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MINE, BOOBY-TRAP, INTRUDER ALARM AND TUNNEL DETECTION

Final Report
Contract No. DAAD05-69-C-0024

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January 1970

TECHNICAL REPORT NO. LWL-CR-02B67 & 01B68

MINE, BOOBY-TRAP, TRIPWIRE AND TUNNEL DETECTION

Final Report
Contract No. DAAD05-68-C-0234

By
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January 1970

U. S. ARMY LIMITED WAR LABORATORY
Aberdeen Proving Ground, Maryland 21005

ABSTRACT

Reports from the field indicated that German Shepherd scout dogs had been observed to alert on mines, tripwires and other man-made artifacts. The purpose of the following program was to explore the feasibility of training such animals specifically to the tasks of detecting mine/tripwires and tunnels, by means of techniques that were sufficiently objective to permit instruction of military handlers in their use.

A six month feasibility study was conducted at the Behavior Systems Incorporated Research Station in Raleigh, North Carolina. Procedures and practices derived from the formal study of animal behavior were used throughout the program. Feasibility was established as a result of a demonstration while at Ft. Gordon, Georgia on July 18, 1968. For details of the demonstration see Appendix A.

Because of the success of this first phase of the problem, a second six months of work was initiated with the objective of training an army scout dog platoon for the capability of mine/tripwire and tunnel detection. This work was conducted at Ft. Gordon, Georgia, using essentially the same techniques as those developed during the feasibility study. The platoon was judged ready and deployed to Vietnam April 20, 1969.

An additional 3 month program was undertaken to study the feasibility of cross-training tunnel and personnel detection dogs. The results of this work were ambiguous.

FOREWORD

The work described in this report was conducted by Behavior Systems Incorporated at Raleigh, North Carolina and at Ft. Gordon, Georgia under contract DAAD05-68-C-0234. The authors wish to acknowledge the technical assistance of other members of the BSI staff, particularly C. Thal and L. Siebert.[1] Appendices B and C were prepared by L. Ondrizek.

Appreciation is also extended to members of the Limited War Laboratory for their encouragement and advice, in particular Dr. Max Krauss and Mr. Milton Cutler, and most of all to Mr. John Romba.

Finally, a word of thanks is due to the enlisted men of the 60th Infantry Platoon and especially to Sergeant John Williams.

In conducting the research described in this report, the investigators adhered to the "Guide for Laboratory Animal Facilities and Care" as promulgated by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences--National Research Council.

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

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[1]BSI is also grateful for the assistance of Dr. R. E. Lubow, C. Fasanaro, R. White, E. Rhew, J. Chipman, C. Chacto, F. Coffey, and J. Vance.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The report to follow will consist of several major parts. Part I is a brief review of the general background concerning the use of animals for unusual tasks, and, in particular, the use of the dog for military applications. Part II will outline the scope of the program as carried out under the contract. Parts III and IV will give details of the two major phases of the program. Part V will discuss the conclusions drawn from the program and recommendations for future operational programs of this type. In Part VI, the appendices, is a rather detailed analysis of an investigation to determine the feasibility of cross-training Tunnel Detecting dogs and Personnel Detecting dogs. The level of analysis in this appendix is quite deep simply because this portion of the program gave ambiguous results, and we would like to set down in writing all the procedures used, so that in the future other investigators would not repeat the same errors.

On the other hand both Phase I and Phase II which accounted for 98% of the program were judged to be successful. Therefore, the same level of analysis is unwarranted in this report. The reader, who wishes to determine the details of the successful training program should consult the training manual for this contract.

I. REVIEW OF THE LITERATURE

The relationship between man and animal, and in particular man's utilization of the lower species can be traced as far back as the earliest recorded history. The use of the brute force of animals was probably one of the first applications, however, as Ulrich, Stachnik and Mabry (1966) conclude:

> " ... Once we eagerly left back-breaking physical tasks to animals better suited to perform them: today we might hope that animals will be allowed to relieve us of some of the more odious 'intellectual' tasks on which the capabilities of human beings for extremely complex judgments and decisions are wasted."

Ordinarily one would expect that with the increase in technological innovations the need for animals would be reduced. Certainly the effects of automation serve to reduce the need for man in many work situations. The paradox, however, is that this technological and scientific revolution has allowed us to make more efficient use of animals. Training procedures, methods and equipment have been developed to such an extent that for many problems the most efficient solution is not a machine, nor a man, but a man-machine trained animal.

Concurrently with the development of new techniques the military has also developed a new set of problems in modern warfare, many of which seem capable of solution by the new man-machine trained organism (M-M-T-O). However, one should recognize at the very outset that the problems in this category do not warrant the M-M-T-O solution simply because they are routine, dull and monotonous for the human, or expensive for the machine, but rather in many instances are a substitute for a human casualty. The trade-off equations comparing the M-M-T-O system and the alternative systems must place heavy weighting on the fact that the M-M-T-O greatly reduces human risk.

For our particular problem concerning the use of dogs to detect mines, booby traps, tripwires and tunnels, there exists very little unclassified relevant research and literature.

That dogs can be successfully trained as personnel detectors has been demonstrated in a variety of situations. Most recently, and directly to the point at issue, is work done by the Canine Laboratory of the University of Maryland under contract with the Limited War Laboratory. They have trained and demonstrated the utility for this purpose of German Shepherd type dogs under actual field-combat conditions. Although this demonstration was limited in scope there are also reports from the field that these same animals alerted on mines, tripwires and other artifacts associated with human scent. It is, in fact, most likely that these animals were responding to scent. Their capability in this modality and the possibilities of employing these capabilities are discussed in two recent reports (2, 3). A popular and somewhat overwritten report of their promise can be found in a recent article by Albino (4).

Other reports, mainly classified, coming from the work done in England in the 1950's, and the work at Fort Belvoir, and recent work also at the Army's

Limited War Laboratory, indicate that the dog may perform a valuable service in the detection of mines, booby traps, tripwires, and tunnels. Nevertheless, it is still necessary to have an unambiguous demonstration of these capabilities, a demonstration contrived after extensive specific training, utilizing the best of current scientific procedures and practice.

II. SCOPE OF THE PROGRAM

The overall objective of the program was to determine the feasibility of training dogs to detect mines, booby traps, tripwires and tunnels. The first six months of the program, Phase I, were conducted in Raleigh at the Behavior Systems Incorporated Field Station. If feasibility could be established, then Phase II would follow. Phase II consisted of training 24 dogs and army handlers at the U. S. Army Ft. Gordon facility. At the successful completion of Phase I and Phase II, which ended the contractor's responsibility on the program, the dogs and men were sent to Vietnam for operational evaluation.

Overall, then, the contracted program was divided into the two phases discussed above, and further subdivided into two tasks for each phase. Task I concerned itself with the training of tunnel dogs; and Task II concerned itself with the task of training dogs to detect mines, booby-traps and tripwires. Schematically then the program was a 2x2 factorial design as represented below:

Phase I Feasibility at Raleigh	Task I - Tunnel Detecting Dogs Task II - Mine, Booby-trap and Tripwire Detecting Dogs
Phase II Operational Training at Ft. Gordon	Task I - Tunnel Detecting Dogs Task II - Mine, Booby-trap and Tripwire Detecting Dogs

III. PHASE I - FEASIBILITY STUDY

A. WORK PERFORMED

TASK I - Tunnel Detecting Dogs

Facilities were constructed to house and maintain 12 dogs. After some selection 12 German Shepherd type dogs were procured. These dogs were between 8 and 18 months of age. They were subjected to veterinarian examination prior to being introduced into the program and were judged to be, in general, healthy, and free of potentially disabling joint anomalies such as hip displasia as shown by X-ray. (Very light colored dogs were also excluded.) In addition, before beginning training all dogs were tested for their "fitness" for training according to the following criteria:

(1) Dogs should not be excessively aggressive nor yet excessively shy and timid.
(2) Dogs should show evidence of inquisitiveness, with a desire to explore the environment.

Once the 12 dogs were selected, the following performance requirements were demanded and met:

(1) Train all dogs in basic and off-leash obedience.
(2) Training dogs to search for, detect and respond to tunnel openings into other ground cavities. Training for capability to detect camouflaged as well as uncamouflaged tunnel openings. Provide at least one true tunnel (sub-terranean passageway) comparable to a typical Viet Cong tunnel, with multiple openings, for training purposes. Other excavations of varying dimensions and configurations were provided by the contractor for training purposes as required.
(3) Train dogs to work both on-leash and off-leash while searching for tunnel openings.
(4) Train dogs to make a specific response in immediate proximity to tunnel openings and openings into other ground cavities. The specific response used was a sit response within a radius of 2 feet of the tunnel opening.

Training techniques were developed to achieve the above requirements. Basically food reinforcement coupled with techniques of approximation were employed. Table 1 shows the level of achievement reached by those dogs completing Phase I. The specific step by step procedures are described in the training manual.

A successful demonstration of the results of these procedures was displayed at Ft. Gordon on July 18, 1968. Details of this demonstration are presented in Appendix A.

TABLE 1

Tunnel Dogs Completing Phase I

Name	Last Grade[1] in Training	Performance during last week of Training Total targets	% detections
Wolf	4	90	92
Junior	4	90	97
Image	4	46	93
Candy	4	90	88
Schnapps	2	39	70
Happy	4	90	72
Shotz	4	70	96
Sarge	4	80	89

[1]All training stimuli were divided into five standardized groups, with each group representing a different degree of visual, tactile, and olfactory concealment. In Grade 1, completely visible stimuli were used. In Grade 5, every effort was made to eliminate tactile and visual cues without regard to the consequent suppression of olfactory cues.

TASK II - Mine, Booby-trap and Tripwire Detecting Dogs

Task II of Phase I had as its major objective to determine the feasibility of training dogs to detect mines, booby-traps and tripwires. This task was run parallel to Task I - Tunnel Detecting dog training. Twelve dogs were selected in a similar manner to Task I, described earlier, and provided with the necessary kenneling space. After selection and adaptation to their new environment the following objectives were sought:

(1) Train all dogs in basic and advanced (off-leash) obedience. Training dogs to search for, detect, and respond to mines, booby-traps and tripwires. The contractor simulated Viet Cong material. Mines were both above-ground, and buried in the ground.
(2) Train dogs to work off-leash up to a distance of 100 meters from the handler, while searching for mines, booby-traps and tripwires.
(3) Train dogs to make a specific response to the presence of a mine, booby-trap, or tripwire, at the target. The response will be compatible with use of a dog-carried motion-sensing radio transmitter. Motion-sensing radio transmitters, special harnesses and matching radio receivers are to be used as a dog-handler common link to permit continuous monitoring of the dog if it goes out of the handler's sight.

Again, the specific detection response that was trained was a sit response within two feet of the artifact of interest. Table 2 shows the performance of the dogs completing Phase I.

TABLE 2

Mine Dogs Completing Phase 1

Name	Last Grade[1] in Training	Performance during last week of Training Total targets	% detections
Heidi	5	44	89
Jack	5	30	80
Panther	5	32	72
Cisco	4	58	79
Toby	5	39	79
Bonnie	4	53	77
Suzy	5	48	74
King	5	37	37

[1]See Table 1 for explanation of Grade.

The techniques developed to accomplish the above were successfully demonstrated (See Appendix A) at Ft. Gordon on July 18, 1968. These techniques, once again, can be found in the training manual.

Some attempt was made to test the reliability of the dog's performance by running two of them, after two weeks rest, on trails 24 hours, 48 hours, and 2 weeks old. The results of this experiment are shown in Table 3.

TABLE 3

Detection Tests Following a Two Week Period of Rest

Time between setting of trail and run	Jack Total targets	Jack % detections	Toby Total targets	Toby % detections
Fresh trails	16	87	16	87
24 hours	16	70	16	78
48 hours	8	25	8	25
2 weeks:				
1st run	4	0	4	25
2nd run	4	75	4	50

As a result of the successful demonstration the contractor was invited to begin the work of training 28 new dogs and 24 men, half each in the tunnel program and in the mine,booby-trap and tripwire program. As part of this requirement three major projects were first completed by Behavior Systems Incorporated.

(1) A 3-hour film illustrating the techniques to be used in troop training.
(2) The construction of a 56 dog kennel facility at Ft. Gordon.
(3) The preparation of training sites at Ft. Gordon.

B. TECHNICAL DEVELOPMENT

The overall problem of training dogs to these particular detection tasks can be conceptualized as working with six relatively distinct behaviors. For convenience, these behaviors will be discussed separately.

1. On and Off Leash Behavioral Control (Obedience)

Early in the program it became apparent that all detection dogs should receive some obedience training for the following three reasons:

a) during the time that the dog is on-duty, performing the detection task, his security will be much enhanced if he will respond promptly to a recall command ("Come");

b) when the dog is off-duty and being transported among other dogs or friendly personnel, the handler will need sufficient control to curb the animal's natural aggressive and exploratory behavior ("Heel," "Down," and "Stay"); and

c) when dogs are required to be easily transferred from one handler to another, it is useful to have some sort of exercise that establishes a "set" in the dog for working cooperatively with a particular handler. Both elementary and advanced obedience ("Crawl," "Jump") work provide an excellent vehicle for such an exercise.

In general, those sections of FM 20-20 that deal with the teaching of on and off-leash obedience were found to be quite adequate.

It was decided that the "sit" command be dropped from the obedience repertoire in order not to confuse the dog by requiring the same response to be made to two completely different sets of stimuli.

2. Response Training

As a result of initial pilot work, it was discovered that before a dog can be taught any response to a non-significant, field situated stimulus, two initial steps must be taken:

a) the stimulus in question must be endowed with sufficient significance to the animal to rank high in his hierarchy of awareness;

b) an approach behavior to the stimulus must be created so that the trainer may be sure that the dog's attention is on the stimulus at the instant response training is initiated.

Both steps were accomplished by placing food in or on the simulated targets, and permitting the dog to feed from them. However, in order for this technique to work, care must be taken to break down the natural tendency for dogs to look to the trainer for cues to initiate responses. Trainers were instructed to

give no commands to the dog except for those absolutely necessary to define the task and, in general, to efface themselves from the training situation as much as possible. It was even found to be advisable to use different personnel for response and obedience training.

Traditional methods of response shaping with continued use of food reinforcement were found to be quite adequate in the field. Partial reinforcement schedules were employed to insure against extinction during later training stages.

In general, once the need for stimulus significance and controlled reinforcement were recognized, little trouble was experienced with response training.

Maintenance of the conditioned sit response over long periods of time should not be a problem, providing at least a 20% food reinforcement schedule is maintained and care is exercised to prevent response generalization from occurring.

3. Detection Training

The exact nature of the stimulus complex by which a dog is able to perform the mine or tunnel detection task was and is unknown. However, several initial assumptions were made.

a) Whatever the nature of the adequate stimulus, it will probably often exist only at very low intensities in the operational environment.

b) The adequate stimulus is almost certainly complex rather than unitary. Its components probably range both within and across sensory modalities.

c) The degrees of stimulus generalization can probably be controlled by limitations on the number of effective components.

d) A dog will habitually utilize the stimulus component involving the least expenditure of energy in searching behavior.

e) Visual stimuli demand less energy expenditure than do olfactory ones.

f) Some components of the complex stimulus will be available at a distance from the source, while others will only be detectable in the immediate proximity of the target. Distal ones may serve as alerting stimuli, but proximal ones must initiate the sit response. The distal/proximal dimension may be defined by intensity increments as well as modality differences.

Because of the low intensity assumption, it was decided to conduct stimulus training over a series of incrementally more difficult problems in order to provide sensitivity training for the dogs.

The assumptions regarding the complex nature of the adequate stimulus led to the use of appropriate secondary stimuli (Task I) and to the use of mine simulators (Task II) containing various mine components.

During response training, a constant and easily detectable stimulus component was needed to enhance training efficiency. In Task II, the targets were therefore left clearly visible. In Task I, a Tunnel Odor Simulant (T.O.S.) was used. During detection training, a graded series of problems was used, designed not only to provide increasing difficulty, but also to force a change from visual to olfactory detection.

The assumed existence of distal cues, usually below human thresholds, necessitated the dog being permitted to set his own pace. Trainers, unaware of such cues, tend to "push the dog off" a target.

In order to insure that the dogs could perform the detection task using only stimuli comparable to those found in the operational environment, much care was taken to eliminate or to randomize any coincidental cues. Coincidental cues were classified as follows:

a) Trainer Associated: It was felt that the only way to insure the elimination of trainer cues was to have him run "blind." A consequence of such a procedure is the requirement of detailed mapping of emplacements if ordnance is not to be lost.

b) Previous Trials in the Same Area. Whereas it is desirable to conduct each trial on a "clean" (previously unused) area, this proved to be virtually impossible from the point of view of practical logistics. In Task II, possible cues from previous runs were eliminated by ensuring that each dog ran a freshly set, different problem from any other dog. The only exception to the elimination of such cues occurred in Task I during Grades I-III. Here the dogs were permitted to track the animals which previously ran the same problem in order to assist directional training as discussed below.

c) Place Learning. This cue was eliminated not only by the exclusive use of unique problems, but also by predetermined, random placement to avoid the location preferences that were shown to occur if the mine layers were permitted free selection.

d) Emplacement Artifacts. Since training emplacements are, of necessity, only simulations of their operational counterparts, some artifacts may result that provide misleading cues to the dog. Considerable effort was exerted to remove freshly turned earth and to randomize the track of the mine layer.

Food continued to provide a satisfactory reinforcer for the stimulus training problems. Social reinforcement was used as a secondary process throughout. However, social reinforcement must be administered carefully and skillfully in order to avoid transferring the dog's attention from the target to the trainer.

The only satisfactory negative reinforcer proved to be an enforced inter-trial interval of from one to five minutes, with the dog being held in the sit

position. Withdrawal of food and social reinforcement were, of course, also present in the design.

The scope of the project did not permit formal experimentation, but certain "educated guesses" could be made with regard to some characteristics of the various target stimuli.

a) Tunnels. It was the feeling of those involved with Task I training, that the dominant component of the adequate stimulus could best be described as "dead air." The term is meant to imply that the olfactory stimuli associated with any object in a confined air space undergoes a qualitative change (distortion) that is identifiable by the dog. This was thought to be true of any stimuli emanating from the walls of the tunnel itself, as well as for objects in it.

b) Tripwires. Close inspection of the dog's locomotion patterns during detection resulted in the frequent observation that they were more closely correlated to those displayed during visual detection tasks as opposed to olfactory tasks. That tripwires present an essentially visual problem was further substantiated by the extremely poor performance of animals with clinically diagnosed poor visual ability.

c) Mines. When mines were employed above ground, with little or no cover, the dog's search behavior indicated the presence of a scent cone much the same as that described by scout dog handlers. However, buried and ground covered emplacements resulted in search behavior much more similar to that exhibited by hounds working "ground scent" or "track." It is probable that the only olfactory cues available from such mines are sufficiently proximal to require the dog's nose to be almost in contact with the source before a final discrimination can be made. In the case of deeply buried mines (three inches or more), it is possible that no source scent exists. The animals may be performing the task by tracking the mine layer. Successful detections of such mines were made after as much as 12 days of emplacement and, Type I (false positives) errors were eliminated from runs in which the mine layer made deliberate "false stops." However, it is possible that some tracking cues were still present in those cases. Controlled experimentation is needed to settle the issue.

4. Directional Training (Task I)

Directional training for the tunnel dogs was integrated with response and detection training. From the first stages of response training the directional hand signal was used and, when followed by the dog, always resulted in successful detection and a chance at reinforcement. Failure to follow the hand signal resulted in a "no," a recall, and another "move out." Permitting the dogs to track a previous, straight-line, successful detection during the first half of detection training further developed the set to follow the trainer's directional signals. No problems with this behavior were encountered in animals that had not received prior scout dog training.

5. Trail Behavior (Task II)

The mine dogs were trained to confine their search pattern to the road or trail upon which they were working. This limitation was imposed from the beginning of response training and was satisfactorily accomplished using the "no" command, combined with recall when necessary. The dog's rate of locomotion and distance from the trainer were also shown to be controllable using clear area practice sessions with the "no," "move out," and recall commands combined with carefully applied social reinforcement.

6. Tripwire Detection

The tripwire detection task was considered to be qualitatively different from mine detection because of the necessary presence of such a strong avoidance component, in addition to the approach component. It was, therefore, decided that a negative reinforcer must be used to prevent the dog from touching the tripwire, even accidentally. Training efficiency would demand that the negative reinforcer be perceived by the dog to be an immediate and direct consequence of touching the tripwire. Electric shock was selected as the most practical negative reinforcer. At first an attempt was made to train the animal using "hot" tripwires. This proved to be impractical because of the excellent insulation provided by the animal's fur. A classical conditioning technique was then invoked. Shock was paired with a buzzer until the latter evoked the same emotional response as the shock. The buzzers were then connected to all tripwires and continued throughout training to serve as negative secondary reinforcers. It should be noted that, whereas the necessity of using a negative reinforcer for tripwire training is acknowledged, its introduction into the training procedures does place a heavier requirement for skill and judgment upon the trainers. The avoidance behavior must be carefully balanced against approach behavior to produce the desired result.

IV. PHASE II - OPERATIONAL TRAINING

A. WORK PERFORMED

TASK I - Tunnel Detection Dogs

Phase II training began at Ft. Gordon August 12. The first week was devoted to classroom instruction in principles and techniques common to both tasks. Field training began on August 22.

The 60th Infantry Platoon (Scout Dog) was divided into two squads with 12 handlers being assigned to the tunnel detection squad. These handlers began working with a total of 25 dogs. The animals came from three sources, as follows:

Ft. Benning	14
LWL	8
BSI	3

By the end of the program it had been found necessary to drop 4 handlers and 11 dogs. During the last month of the program, one handler was transferred from the mine to the tunnel squad for a final total of 9 tunnel detection handlers with 14 dogs.

Drops from the program were made for the following reasons:

Handlers:
- 1 removed from training to attend English Language School,
- 1 removed from training because of an inability to understand and perform as a tunnel dog trainer,
- 1 removed from training because of an unwillingness to follow procedures and train his dogs correctly.
- 1 removed from training for disciplinary reasons

Dogs:
- 7 dropped for medical reasons
- 4 dropped for behavioral reasons (excessive shyness)

On February 5, control over the training program passed out of BSI hands and became the responsibility of the command structure of the 60th Infantry. A skeleton BSI staff remained at Ft. Gordon to act in an advisory capacity. This arrangement, however, did not prove to be satisfactory. It was the opinion of both LWL and BSI that the 60th did not have either the technical or logistic capabilities to conduct effective, on-going training. As a result, the much reduced BSI staff resumed responsibility over some aspects of the program, such as scheduling and supervising of procedures. This structure continued until the completion of the contract on April 6.

Throughout Phase II, both men and dogs were trained in the techniques and procedures developed during Phase I. In addition, considerable training time was devoted to providing the handlers with sufficient control over their animals to comply with the requirements of tactical field deployment. Table 4

shows the animals' performance as of January 27, the last summary for which accurate data from the field was available. BSI did not consider the tunnel detection dogs' performance on tripwires to be satisfactory. This can be attributed in part to the late date (December 2) that the decision was made to incorporate this capability, and in part to the difficulty experienced in obtaining the materials necessary for the work.

TABLE 4

Tunnel Dog Performance[1]

Dog	Total Tunnels	Per cent Detections	Total Tripwires	Per cent Detections	Total Targets	Per cent Detections
Smokey	43	93	35	63	78	79
Elmore	70	90	64	64	134	78
Trojan	57	84	45	49	102	69
Willy			DATA LOST			
R.V.	67	90	65	83	132	86
Rinty	50	100	50	70	100	85
Rebel	59	98	55	59	114	80
Thor	44	100	43	74	87	87
Scout	68	96	59	75	120	86
Butch	61	97	65	81	133	89
Tora	69	96	55	66	124	82

[1]This data was collected from the time the dog began integration (tripwires with tunnels) training up to the time the 60th took over training.

TASK II - Mine, Booby-trap and Tripwire Detection Dogs

Phase I, Task II, training also was conducted at Ft. Gordon and followed the same time frame as that already described above for Task I.

The 12 handlers assigned to the mine detection squad began the program with 28 dogs from the following sources:

Ft. Benning	14
LWL	8
BSI	6

By the end of the program it had been found necessary to drop 15 dogs as follows:

9	for medical reasons
6	for behavioral reasons

During the last month of the program one handler was discharged from the service and one was transferred to the tunnel squad. The final complement was therefore composed of 10 handlers with 13 dogs.

As for Task 1, the training techniques and procedures used were those developed in Phase I with the addition of more elaborate off-leash control training. Table 5 describes the performance of the mine detection dogs during the period from December 30, 1968 to February 5, 1969.

TABLE 5

Mine Dog Performance[1]

Dog	Total Mines	Per cent Detections	Total Tripwires	Per cent Detections	Total Targets	Per cent Detections
Lobo	128	77	68	81		79
Andy	140	77	72	83		80
Suzy	108	54	72	86		70
Toby	144	71	95	85		78
Shane	116	73	74	69		71
Chief	132	79	83	73		76
Panther	96	77	76	67		72
King	112	64	76	74		69
Ricochet	136	55	104	85		70
Heidi	104	78	61	84		81
Becky	112	55	70	87		71
Kim	116	84	66	68		76
King	84	71	52	67		69
Toby	148	61	68	75		68
Bonnie			DATA NOT AVAILABLE			

[1]This data was collected from all runs between December 30, 1968 and February 5, 1969.

B. TECHNICAL DEVELOPMENT

During Phase II, essentially the same training technology was used as had been developed in Phase I. However, some useful observations were made with regard to two new variables, i.e., the introduction of military handlers and the use of previously trained dogs.

1. Obedience

In general, the military handlers were found to execute voice and hand commands with great precision, were comfortable working with their dogs, and had developed some reserves of patience. They were, however, poorly trained in FM 20-20 and displayed little understanding of the learning process. Their timing was poor, resulting in incorrect stimulus pairing, and their reinforcement techniques ("busting," "airplane spin," "hanging") were not appropriate for off-leash work.

Those dogs which had already graduated from the on-leash scout dog course proved to be much more difficult to train than the naive animals. They required from 100% to 150% more training time and even then, many individuals never showed adequate transfer. Much habitual resistive behavior was present, and off-leash control was difficult to maintain because of the previously well established, proximal control boundaries resulting from prior reinforcement techniques combined with solely on-leash training.

2. Response Training

Various delays in the program resulted in the need for increased training efficiency and the 20" reinforcement schedule used in Phase I was dropped from the procedures. This would appear to have been a superfluous step, since no sign of response breakdown was evidenced in the later stages of training.

Much energy and time were expended in attempting to retrain the military handlers with regard to the meaning and use of reinforcement in the learning process. Little success was experienced. By the end of the program, the handler still conceptualized food reinforcement as a simple reward for overall cooperative behavior in the shallowest sense.

Negative transfer in handler training also proved to be a problem in the area of response generalization limitation. It would appear that the scout dog handler is taught to encourage response generalization as much as possible. This is probably due to the non-specific nature of the response used (alert). However, without limiting procedures, the very precise (sit within two feet) response of the special detection dog will break down rapidly.

Response training was prolonged by approximately 20% due to sporadic breakdowns in target significance. This problem did not arise during Phase I. It was hypothesized that the difficulty lay with the previous "sit" command training that the animals had received. This would tend to inhibit the re-direction of the dog's attention away from the handler and toward the target.

3. Stimulus Training

Real ordnance targets were introduced for the first time in Phase II. Little difficulty was experienced in making the transfer when a slow (10 days) phasing in period was used. However, it is possible that the dogs did not have enough experience with the low intensity components of the complex target stimuli to achieve maximum efficiency. It would be desirable to employ a constant class of target stimuli from the initiation of stimulus training throughout the dog's working life.

It was found that the degree of stimulus generalization could be easily controlled and maintained by suitably sampling the desired class to use for training and maintenance stimuli. This would predict an easy transfer from simulated to operational problems. Again, the handlers proved unwilling to control stimulus generalization, apparently because of their desire for their dog to perform in a non-specific, all encompassing, protective capacity.

Most handlers quickly grasped the significance between the dog's proximal and distal search behavior and displayed little tendency to "push" the dog off target. They proved considerably more resistant to the need to eliminate coincidental and trainer cues, the need for problems of controlled difficulty, and the need for the dog's attention to be directed away from itself.

Previous training and/or selection was credited with being responsible for the moderate savings in training time exhibited by the scout dogs as opposed to the naive and relatively unselected control group.

4. Directional Training - Task I

This proved to be the most difficult problem in Task I for Phase II. Experience in training dogs in the off-leash mode showed that the animals tend to establish a control boundary. That is, at any given stage in training the dog will adequately respond to the handler's commands as long as he is within certain distance limits. If the handler permits the animal to exceed this limit, he loses control. Successful training involves the gradual extension of these boundaries until they are beyond the dog/handler distance required. The procedure goes from the five feet provided by the short leash to the 25 feet provided by the long leash, and from there on out by the "no" command with recall. Scout dogs, trained exclusively on leash, were found to have a long established control boundary at about five to six feet. Beyond this distance, they proved uncontrollable and reluctant to return to the handler. In spite of the allocation of considerable extra training time to the practice of this behavior, scout dogs were judged to be only marginally under control by the end of the program.

5. Trail Behavior - Task II

The problems and observations discussed under Directional Training above, were also applicable to trail behavior.

Neither close gunfire, groups of people following, nor a pre-run helicopter ride proved to be an effective external inhibitor to either detection work or control behavior. This was also true for the Task I, off-leash directional work.

6. Tripwire Training

No new problems arose during Phase II tripwire training. This may have been due to the obvious difference between this procedure and those experienced previously by either dogs or handlers.

SUMMARY AND CONCLUSIONS

PHASE I

During Phase I the ability of German Shepherd type dogs to detect mines, booby-traps and tripwires and to detect tunnels was demonstrated. The procedures developed by the BSI staff were derived from formal studies of animal behavior and reinforcement theory. The success of this method of approach as opposed to the "art" of dog training was repeatedly shown in the reliability and efficiency of training. Most important, however, the objectivity of the BSI approach allowed us to communicate techniques to people without "dog experience" and thus in a later phase of training to turn a completely "naive" platoon into an operational dog-man system.

Two other points are worth noting for Phase I. There is a need for the final desired behavior to be specified prior to training. That is, it is important for the military to clearly and precisely define the field operational situation before training starts. It is, for many reasons, difficult to change procedures once training has begun. In some cases there is not merely adding training time on a 1 to 1 basis, but often there is "negative transfer," where the first training interferes with the acquisition of the newly required piece of behavior. All of which calls for careful analysis at the beginning of such programs of the systems operational requirements.

PHASE II

During Phase II the procedures developed during Phase I were used to develop an operational platoon, half of which were trained as mine, booby-trap and tripwire teams and half as tunnel teams.

Although this phase was successful, the experience gained suggests that, until suitable professional personnel are made available by the military, future programs be accomplished by private industry. We believe that training can be conducted more efficiently in both time and cost if the entire dog training were left to professional personnel, with the military personnel being trained to be dog handlers rather than dog trainers. Although there is perhaps some loss of flexibility with this approach, it is deemed to be a considerably more reliable one over the long run. In conjunction with this point, it would be desirable for future army handlers to be selected on the basis of "liking" dogs, but also on the basis of their not having any formal experience training dogs. Again, negative transfer seems to be a powerful phenomenon in this situation.

A final, and perhaps obvious, conclusion for this section is the need for dogs to be in top physical shape. Poor health interferes with the efficiency of training, to an extent that maximum veterinary care should be supplied to insure the dogs being in the best health.[1]

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[1]During Phase II, with a fairly large sample of dogs, of those animals dropped from the program, 62 per cent were dropped for medical reasons and 38 per cent for behavioral reasons. This, in spite of the fact that all dogs were screened medically and only about half were screened on behavioral criteria.

In summary, then, the application of training principles derived from behavioral reinforcement theory has allowed us to demonstrate that dogs can be trained to detect mines, booby-traps, tripwires and tunnels, and that men can be trained to use these dogs. Together, a successful system was produced and demonstrated.

REFERENCES

1. Ulrich, R., T. Stachnik, and J. Mabry. Control of Human Behavior. New York: Scott, Foresman, 1966, p.238.

2. Smith, C. M., and J. M. Coates. Olfaction and its potential application in personnel detection. Institute for Defense Analysis. Research Paper, p.187, May 1965.

3. Hefter, M. Personnel detection study. Contract No. DA 18-001-AMC-218(X). Final report by Kollsman Instrument Company to Electronic Research Branch, LWL, February, 1964.

4. Albino, J. Four footed radar in Vietnam. Popular Mechanics, Sept., 1967.

Appendix A

Phase I Final Demonstration for Phase I

Date: July 18, 1968

Attending: John Romba, Major L. Lenoci, Dr. Max Krauss, Milt Cutler, Colonel R. W. McEvoy, Dr. Clint Maag and others

Description: At 7:00 A.M., July 18, the demonstration began with a briefing session conducted by Miss Carr-Harris. Following this session, the demonstration was held in the training area provided for BSI. The first group of dogs demonstrated were the mine and booby-trap detectors. The dog, Jack, worked a trail through the woods and made positive responses to 80 per cent of the stimuli. The second mine dog worked was Heidi, whose trail included both a wooded area and a small well-traveled sandy road. She responded to 100 per cent of the stimuli, however, the last portion of the run, on the road, was extremely slow due to the difficulty of locating a deeply buried mine on a well used road. The last dog of this group, Willy, was trained as a tripwire detector. His trail was through a heavily wooded area with dense underbrush. He detected 90 per cent of the stimuli.

After a short break for refreshments, the demonstration continued with the evaluation of the tunnel detecting dogs. The first dog, Wolf, worked in an area comprised of pine woods and a well-traveled dirt road. He made positive responses to 100 per cent of the stimuli. The next dog, Shotz, worked a road which entered into a village and the village area. She detected 80 per cent of the tunnels, missing one which was under a recently used campfire. The last dog, Image, worked an open area and a simulated graveyard and found 100 per cent of the tunnels. She also detected a tunnel which had been dug by one of the visitors. It should be mentioned that all stimuli were at the highest level of concealment (Grade 5) designed by BSI.

After lunch, all visitors returned for a de-briefing session conducted by Miss Carr-Harris.

Appendix B

Some Comments on Obedience Training for Detection Dogs

At the outset of any research program, the values of the relevant parameters are determined simply on the basis of the knowledge of the investigators, as to what they want and as to what is plausible from previous data and techniques.

Accordingly, at the outset of this program several such parameters were fixed, largely by consensus of all the principal persons involved in the project from LWL and BSI. And, naturally, there were indeed highly plausible assumptions, given the prior data and techniques available when they were made. Among such assumptions was one critical one: that the feasibility of such animal-sensor use will be maximized by employing training techniques which are essentially "conventional" and typified by the techniques for training scout dogs, whether civilian or military.

The plausibility of that assumption stems from several sources. It is the training basis for the military scout dogs in which mine-detecting behavior was first casually observed at the outset. It is the training basis, and an avowedly effective one, for nearly all dogs which are used in any serious roles as extensions of man's own capabilities: A notable exception is in the training of circus dogs, in which spealized and highly sophisticated shaping techniques are added.

The essential features of all such training methods revolve around a regime of exceedingly rigid discipline--substantial obedience training prior to the introduction of any other training, and training methods which are oriented towards efficiency (not effectiveness) of response elicitation and efficiency in the logistics of the trainer-animal relationship. Such methods are, of course, excellent, and highly recommended for many of the tasks for which they are employed, in which the behavior is often quite straightforward and sophisticated, judgmental or discrimination capabilities are not required. Moreover, they have one special consequence which for such uses as mentioned above is often highly advantageous, but which for our use was apparently disastrous: they tend to make the animal overly trainer-conscious, to the detriment of the potential effectiveness of any other stimuli in the environment, as a trigger to elicit some desired behavior.

Our particular program was well suited to the testing of that hypothesis (if it may be so regarded for the sake of explication) in several respects, one of which was the selection of training staff. Our chief trainer had extensive obedience training for the domestic hunting-dog and pet market. The remaining training staff included several men with recent military scout-dog training experience.

This permitted a strong orientation towards what was briefly described above as "conventional" training methods; it was "by the book" at several levels of

interpretation. In particular, advanced (reconnaissance) training was conceived as a logical extension of obedience training, both in spirit and in temporal sequence, discipline was characteristically rigid, and typically heavy use was made of the choke-chain as a negative reinforcer.

Following extensive obedience training, advanced training was carried with several dogs to a point at which we felt that a reasonable, though cursory and informal, evaluation of performance could be made. Despite the informality and brevity of the evaluation, the results were quite clearly and unambiguously negative.

Thus, by way of a partial and preliminary answer to the question of feasibility which this program is intended to provide, it is our opinion that--using conventional training techniques of the kind which rely substantially on negative reinforcement and obedience to the handler--it is not likely that a dog can successfully accomplish this reconnaissance function.

Appendix C

Human Detection Training Combined with
Tunnel Detection Training

Human Detection Training (HDT) Text Outline

I. Introduction

A. Contract Identification
B. Contract Purpose
C. Functional Objectives

II. General Procedures

A. Work Locations
B. Personnel
C. Dogs
D. HDT Stimuli - Response - Reinforcement

III. Work Procedures

A. Introduction
B. Tunnel Training Maintenance
C. HDT - 1
D. HDT - 2
E. HDT - 2A
F. HDT - 2^1

[dates in effect, physical description, special problems, raw data, analysis, interpretation, conclusions, lead-in to next training stage]

Human Detection Training (HDT)

Final Report

I. Introduction

A. Contract Identification

This report describes the research project undertaken by Behavior Systems, Inc., Raleigh, N. C., in fulfillment of addendum P010 to contract DAAD05-68-C-0234 granted by the U. S. Army Limited War Laboratory, Aberdeen Proving Ground, Aberdeen, Maryland. The effective period of addendum P010 was from 10/7/68 to 1/7/69.

B. Contract Purpose

The purpose of addendum P010 was to determine the feasibility of the addition of a human detection capability to the behavioral repertoire of non-aggressive war dogs previously trained to detect and respond to concealed tunnels or to mines, tripwires, and booby-traps. The human detection training (HDT) was to be integrated with the dog's previous tunnel or mine detection training such that a correct response to the detection of a human would be discrete for that stimulus and easily distinguishable from the response to the tunnel/mine stimuli.

C. Functional Objectives

The functional objectives of this feasibility study were drawn from the addendum objectives by project personnel after consideration of the constraints imposed by the availability of time, funds, personnel, and suitable animals. At the time addendum P010 was to begin only tunnel detecting dogs were available for study.

The functional objectives which guided training efforts in this project were the following:

(1) To determine the methodology for training non-aggressive war dogs to detect and respond to the presence of potentially hostile, visually concealed humans in a variety of field situations.

(2) To establish a response to the human stimulus that was discrete in a dog's behavioral repertoire and not in conflict with the previously learned sit response to tunnel stimuli.

(3) To train each dog to respond to the human stimulus at the maximum distance of which the dog was capable and to maintain that response until instructed otherwise by the handler.

(4) To integrate human detection training with the tunnel detection training which each dog would be capable of discriminating between and would yield differential responses to the presence or absence of humans in detected tunnels.

(5) To train each dog so that the response to a human superceded the response to a tunnel when both stimuli were present simultaneously.

II. General Procedures

A. Work Locations

All of the dog training under addendum P010 was conducted on or near the Behavior Systems, Inc. field station located on County Road 1390 in southwest Wake County, North Carolina. Approximately 750 acres of woodlands and fields were intensively used for certain phases of training, and approximately 50 miles of county-maintained, unimproved secondary roads were used in another phase of training.

C. Dogs

Four German Shepherd dogs were made available for this project from among the tunnel trained dogs kenneled at Ft. Gordon, Georgia. Each of these dogs had been trained previously to a grade 4 or 5 proficiency in tunnel detection by BSI personnel. Three of these dogs were returned to the BSI field station on 9/27/68 and the fourth was returned on 10/17/68. The dogs used in this project were the following:

CANDY: 16 months old female; received from Ft. Gordon on 9/27/68
IMAGE: 22 months old female; received from Ft. Gordon on 9/27/68 dropped from HDT on 1/21/69 due to an incapacitating interdigital infection
SARGE: 21 months old male; received from Ft. Gordon on 9/27/68; dropped from HDT on 12/2/68 due to an incapacitating interdigital infection
WOLF: 17 months old male; received from Ft. Gordon on 10/17/68

D. HDT Stimuli - Response - Reinforcement

The human stimuli deployed as targets in HDT were adult males. They wore civilian work clothing of an assorted variety, and, for use with suitable backgrounds, they were provided with camouflage-colored hooded rain ponchos. A designated target trainer was responsible for the instruction and exact field deployment of targets before any given dog run or series of runs. In most cases targets were deployed individually, although occasional multiple-target ambushes were set up to expose the dogs to such situations.

It was beyond the scope of this study to determine the exact human characteristic which cued a dog to the presence of a target. A unique cue possibly did not exist. During the course of HDT the most obvious human related cues were suppressed or eliminated until only olfactory cues were available to a working dog. Then the total olfactory cue potential was altered by such techniques as masking a target's odor by his deployment near burning cat litter,

farmyards, lumber piles, sewage, etc., or by putting the targets in spider pits which were fitted with camouflaged, solid plywood covers. The labor turnover experienced in this project insured against the dogs becoming familiar with a particular set of human target odors.

One of the functional objectives [I.C.(2)] of this project was to establish a response to the human stimulus that was discrete in a dog's behavioral repertoire and not in conflict with the previously learned sit response to the tunnel stimulus. Two potential responses merited serious consideration. The first was the standing "freeze" response with the dog upright, silent, and not moving. The second was the "down" response with the dog silent and in a prone position (e.g., see FM20-20, Fig.20). These both were natural body positions for a dog to assume, highly visible to a handler within sight, amenable to possible radio monitoring of an off-leash dog, silent, and would stop the dog's progress toward a potentially hostile human.

The standing freeze response had one serious fault which was not inherent in the down response. The freeze response would have required the handler to interpret his dog's behavior. It had been our experience that many dogs would effect a standing freeze response as a part of their total alert to any novel stimulus. If a freeze response was to be associated with a particular stimulus, such as a human, either the dog would have had to be trained so that its natural alert-freeze to all other stimuli was no longer permissible behavior, or else the handler would have had to learn to distinguish between the conditioned freeze response and the naturally occurring alert-freeze. Neither alternative was particularly desirable because the former would have been very difficult to teach to a dog, and the latter would have placed an unnecessary burden on the handler's judgment.

The down response, once conditioned, was less subject to misinterpretation. Lying down was not a naturally occurring behavior of a tunnel trained dog while working. If the down response was associated with the human stimulus, it would be very discrete in a dog's behavioral repertoire. A down repertoire. A down response also afforded the dog a slight advantage in personal safety over a standing freeze response, as well as being more comfortable to maintain until the trailing handler could ascertain the safety of further movement. It was decided for the above reasons to train for the down response.

The food reinforcement used throughout HDT, unless otherwise specified, was a commercially available, pelletized, slightly moist dog food, Prime. The quality of food reinforcement given for various successful behaviors was occasionally adjusted to meet existing contingencies, but most often it was set by rough ratios. The quantity of Prime/day available to a dog was based on body weight at a ratio of 1 bag/16 lbs., minus one bag/day for continuous food deprivation. The quantity of Prime/run available to a dog was a fraction of the quantity of Prime/day, 1/no. of runs, for that day. The quantity of Prime/good response available to a dog on a given run was a fraction of the quantity of Prime/run, 1/no. of stimuli, for that run. Each dog's performance determined the quantity of food it received from the quantity that was available. If it correctly responded to all stimuli on a run, it received all the food available for that run. In the event of continued poor performance, however,

adjustments were made to prevent the dog from losing more than 15 per cent of its normal body weight. Food reinforcement was always supplemented with verbal reinforcement in HDT.

III. Work Procedures

A. Introduction

Several factors combined to necessitate an empirical approach to this feasibility study. The time constraint, the limited subject pool of dogs, and the lack of methodological standardization in the area of human detection training weighed heavily against even limited experimentation.

The following detailed HDT procedures resulted from this empirical approach. They were derived and put into effect by the project team in attempting to achieve the functional objectives within the multiple constraints then existing.

An incremental progression of defined training stages was attempted to allow analytical evaluation of intrastage learning and interstage progress of the subject dogs. As training progressed under each HDT stage, unanticipated or uncontrollable factors which influenced training were noted, but many of these were not amenable to analytical evaluation within the scope of this project. Wind direction and strength for example, was a primary source of variability in the dogs' performance, yet due to a lack of portable wind measuring equipment, no relevant objective data could be recorded for later correlation with performance.

The description, analysis, and evaluation of each HDT stage which follows represents what has been attempted and accomplished on this project. Section IV summarizes our recommendations for future studies in the area of human detection training based upon the findings and experiences presented here.

B. Tunnel Training Maintenance

One of the functional objectives [I.C.(4)] of this project was to integrate HDT with the tunnel detection training which each dog previously had undergone such that each dog would be capable of discriminating between and would yield differential responses to the presence or absence of humans in detected tunnels. If this objective was to be accomplished, it required the maintenance of the dogs' previously acquired tunnel detection behavior at a degree of proficiency at least equal to the detection task planned for this stage of training. In this integration training stage the planned tunnels were to be cylindrical pits, 4 ft. deep by 3 ft. in diameter, and fitted with camouflaged, 3/4 in. solid plywood covers. It was determined from this information that a grade 4 proficiency in tunnel detection should be maintained as an acceptable minimum.

Several factors influenced the extent and timing of the maintenance training conducted during this project. The more important of these were the retention of previous tunnel detection training by the dogs, the time available for

maintenance runs, the availability of dog handlers, and the logistics involved in transporting the dogs from the HDT training sites to the tunnel grids.

It was necessary to test the first three dogs returned from Ft. Gordon for their retention of previous tunnel detection training because they had been inactive for several weeks. This was accomplished by starting each of the three dogs at the sit training stage of tunnel detection training and allowing them to progress as rapidly as they would achieve the criteria for successive training grades. When each dog met or exceeded the criterion for grade 3B all subsequent maintenance training was conducted on grade 4 tunnels. The fourth dog returned from Ft. Gordon was at a current grade 4 proficiency in tunnel detection, therefore its maintenance training was kept at that level.

A second dog trainer joined our project staff on 11/5/68 and handled all maintenance runs after that date.

C. HDT - 1

The HDT-1 stage was in effect from 10/22/68 to 10/31/68 inclusive, a total of eight working days. The purpose of HDT-1 was to associate the down response with the presence of the human stimulus (i.e., target), primarily through sudden visual contact, although olfactory and auditory cues were a part of the stimulus conglomerate. Diagram Figure 1 below was the reference diagram for HDT-1.

When available, five targets were deployed before each dog run in a relatively open area (e.g., an overgrown field), in a line, spaced approximately 30 m. apart, and each target concealed himself on ground level as well as possible from the subject dog's vision.

The subject dog was brought from the stake-out area to the beginning of the run, harnessed, kept on short leash, and was commanded to move out in the direction of the nearest target, who was at least 30 m. from the start point. The command to move out marked the beginnings of the run and the first trial.

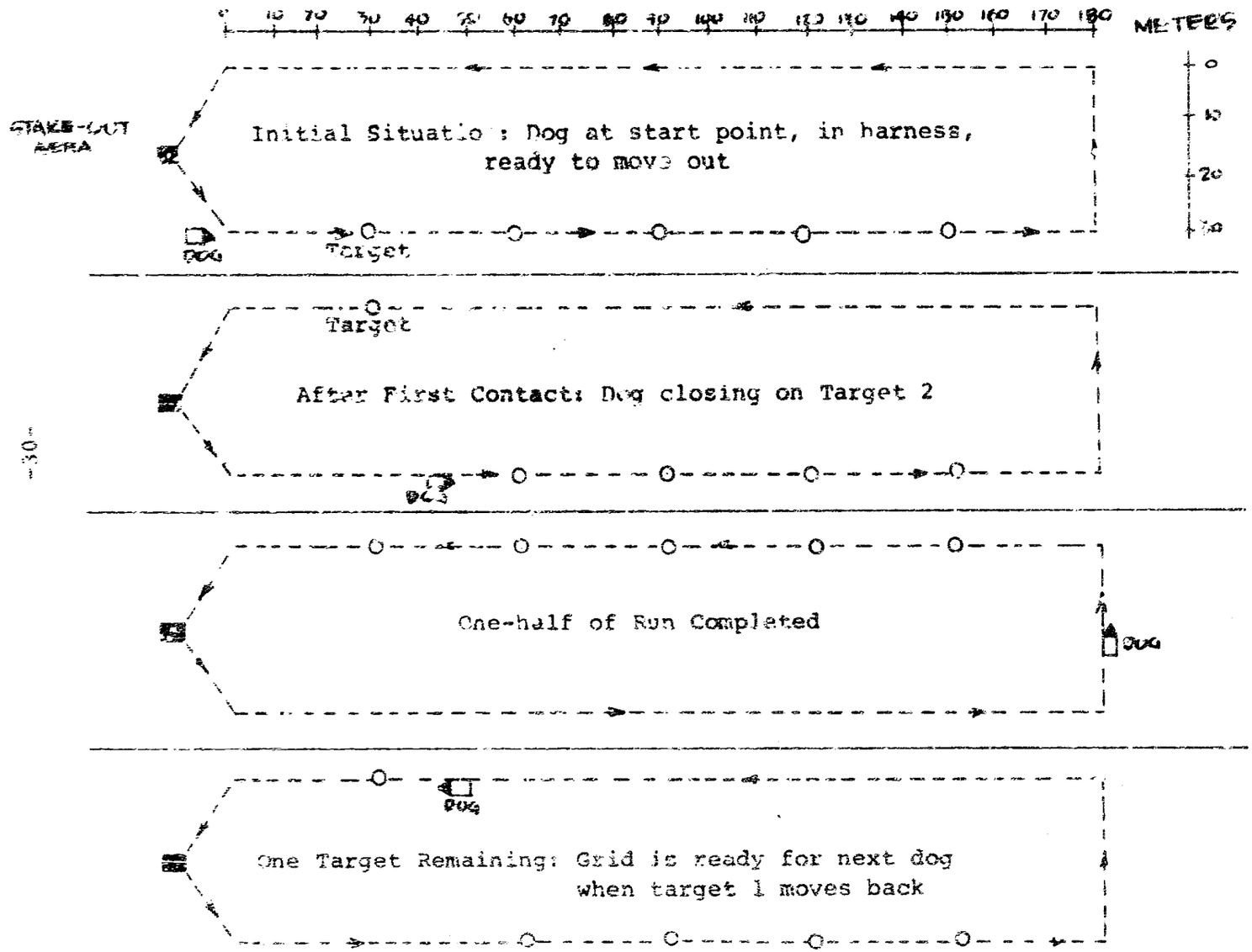
When the dog closed on the first target to a 20 ft. line-of-sight distance, the target moved quickly to become fully visible to the dog. The target stood in place facing the dog for a silent count of two seconds, then ran fast approximately 30 m. to his right along an imaginary line perpendicular to the original line of targets and took a new hiding position.

One second after the moment of contact, the handler, without verbal command, would force the dog into a down position, oriented toward the target, and then would reward the dog with hand-fed Prime and praise.

After the target had cleared the immediate area and had resumed hiding, the dog was commanded to move out in the direction of the next target in line. This command to move out marked simultaneously the end of the first trial and the beginning of the second trial. On the second and all subsequent trials of the run, the procedures were a repetition of those in the first trial.

FIGURE 1:

Sequential Diagrams of HDT-1 Field Situations



As the dog was worked along the original line of targets, a new line of targets would be established which was 30 m. away from and parallel to the original line with the 30 m. target spacing intact. The dog was returned along this new line of targets, who, after contact, would be returned to the original line of deployment by following the same repetitious procedure. The number of trials per run was thus twice the number of targets deployed.

The handler worked the dog on all trials following the same procedures, except that after the final target had been contacted in a run, the dog was taken off-leash and given obedience drill across the distance to the stake-out area. A run did not end until the dog was unharnessed and given a break period at the stake-out area. The handler would determine the end of the break, exchange dogs, and lead the next dog to the start point to begin its run.

This procedure was followed until a dog voluntarily responded on three trials in succession within the same run. Thereafter, reinforcement became contingent upon good responses to the targets. A good response was a voluntary down in the presence of a suddenly visible target. If a dog's response anticipated the target, the target would move immediately to make himself visible to the dog, then the reinforcement was administered.

Figure 2 is a graph of the subject dogs' individual learning curves during HDT-1. There are two disjoint curves for each dog. Those curves in the lower left of the graph are based on the daily percentage of voluntary responses of each dog while undergoing basic response training. Those curves in the upper right of the graph are based upon the daily percentage of good responses of each dog during that part of HDT-1 in which reinforcement was contingent upon the response.

The two curves for any given dog are artificially disjoint to demonstrate the trial and percentage of voluntary response juncture at which basic response training ended and response contingent reinforcement trials began. They could be joined into a continuous curve with no loss in descriptiveness.

It is apparent in Figure 2 that the dogs divided into two subsets of two dogs each based on their rates of learning. Image and Wolf demonstrated a more rapid rate of learning than did either Candy or Sarge during the response contingent reinforcement trials. No explanation of this situation can be offered except that it reflects the individual differences of the subject dogs.

Table 1 presents a summary of the HDT-1 performance of each dog and for the dogs as a group. Under the tenuous assumption that this sample of four dogs was representative of the population of tunnel detection trained dogs from which it was drawn, the group summary would represent our best available information as to various training expectancies should other tunnel detection trained dogs subsequently be entered into HDT

The group summary in Table 1 shows that an average of 111.5 trials were necessary to establish the basic response to a suddenly appearing human. It required an average of 102 response contingent reinforcement trials for the group average of good responses to reach 67.98.

Figure 2: LEARNING CURVES
HDT-1

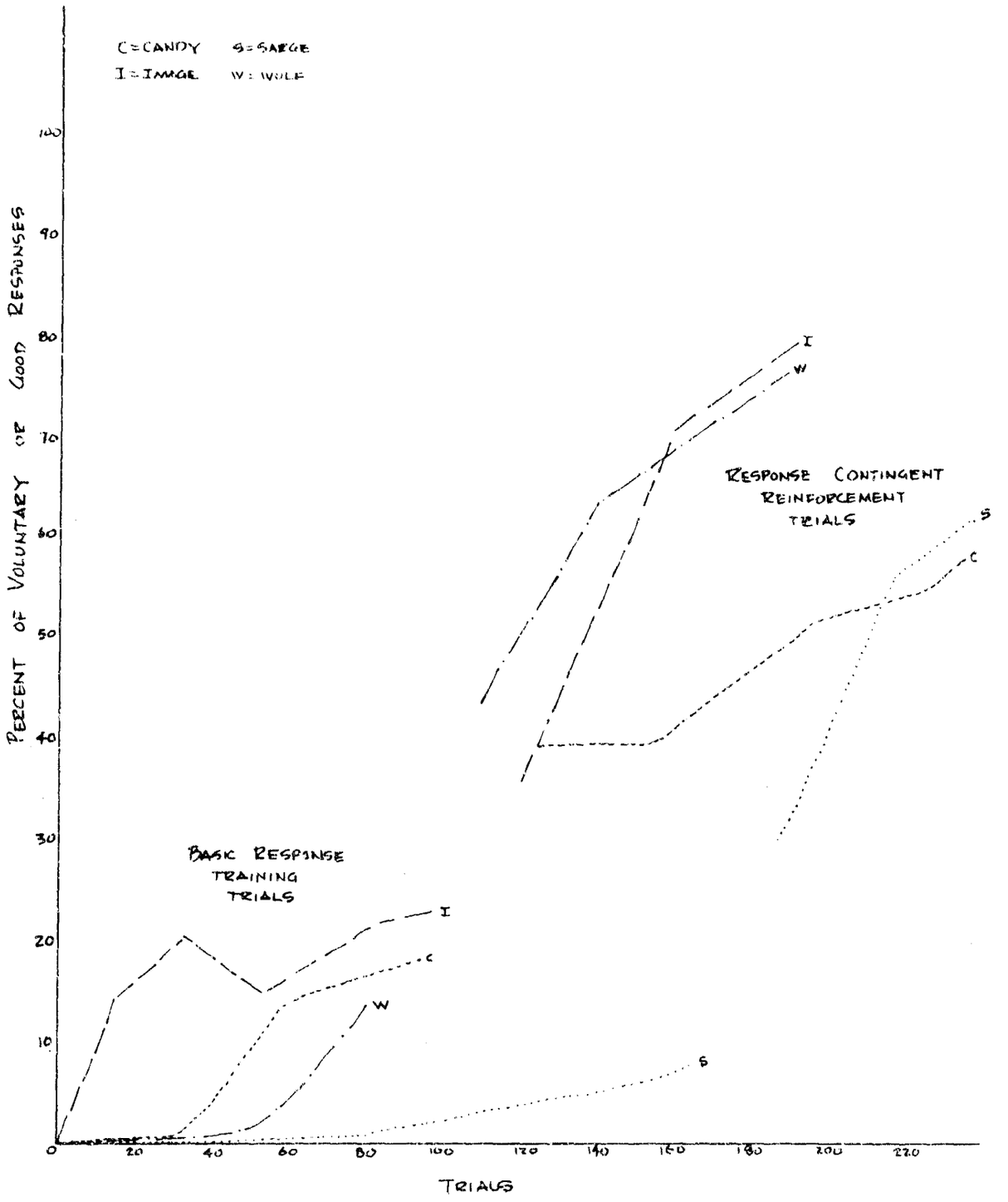


Table 1: HDT-1 Grouped Data

Dog	Total Targets	Total Runs	Average No. Targets Per Run	Total Involuntary Responses	Total Trials	Per cent Involuntary Responses
Wolf	190	20	9.90	69	80	86.25
Candy	236	25	9.44	80	98	81.63
Image	190	20	9.90	77	100	77.00
Sarge	238	25	9.56	154	168	91.67
	854	90	38.80	380	446	336.55
Group	213.5	22.5	9.70	95	111.5	84.1375
Summary	552.75	6.25		1176.50	1124.75	
	23.5106	2.5000		34.3001	33.5373	

Table 1: (continued)

Total Voluntary Responses	Total Trials	Per cent Voluntary Responses	Total Good Responses	Total Trials	Per cent Good Responses	Total Bad Responses	Total Trials	Per cent Bad Responses
11	80	13.75	81	110	73.63	29	110	26.37
18	98	18.37	80	138	57.97	58	138	42.03
23	100	23.00	71	90	78.89	19	90	21.11
14	168	8.33	43	70	61.43	27	70	38.57
66	446	63.45	275	408	271.92	133	408	128.08
16.5	111.5	15.8625	68.75	102	67.98	33.25	102	32.02
20.25	1124.75		236.1875	632.00		218.1875	632.00	
4.50	33.5373		15.3684	25.1396		14.7712	25.1396	

On the final day of HDT-1 each dog, except Sarge, exceeded an 80% good response performance level on two successive runs. Sarge's performance level on that date was 75%. All the dogs were advanced to HDT-2 together. This was necessary because it was not possible to run the dogs on separate stages of training without placing undue stress on our single trainer and the target personnel. HDT-2 was also a rational extension of HDT-1 and did not change the learning situation too greatly.

D. HDT - 2

The HDT-2 stage was in effect from 10/31/68 to 11/7/68 inclusive, a total of six working days. The purpose of HDT-2 was to accustom the dogs to targets concealed in woods and to continue their acquisition of responses based on olfactory cuing.

In a typical HDT-2 run, five targets were deployed along one of two roughly parallel woodland trails which were no less than 50 yards apart. The trails had been marked with numbered stakes at 20 ft. intervals. The targets each were assigned a "base" stake number on each trail and were allowed a two stake tolerance on either side of their base stakes as the areas in which they could conceal themselves during a run. The base stakes were at 400 ft. from the start point of the run.

The subject dog was brought from the stake-out area to the start point, harnessed, kept on short leash, and was commanded to move out on the trail along which the targets were deployed. The command to move out marked the beginnings of the run and the first trial.

If the dog closed on the first target to a distance of 40 ft. without responding, the target would quickly move from his concealment to become fully visible to the dog. The target stood in place facing the dog for a silent count of five seconds, then quickly ran to the second trail and resumed hiding.

If the dog responded to the target with the down response, the handler would reinforce it with the quantity of Prime allowed for that trial, verbal praise, and petting. If the dog failed to respond or incorrectly responded, the handler would correct the dog by placing it in the appropriate down position.

If the dog responded to the target at distances greater than 40 ft. the target would immediately reveal himself, then the dog was reinforced by the handler.

After the dog had been reinforced or corrected and the target had moved to his position on the second trail, the dog was commanded to move out along the first trail again. This command to move out marked simultaneously the end of the first trial and the beginning of the second trial. On the second and all subsequent trials in the run the procedures were a repetition of those in the first trial.

As the dog was worked along the first trail, the targets' movement would set-up the second trail for the dog's return. When the dog was returned along

the second trail, the targets' movement would set-up the first trail for the next dog's run. The number of trials per run was thus twice the number of targets deployed.

A given run ended when the dog had travelled both trails and was given a break period at the stake-out area. The handler would determine the end of the break, exchange dogs, and lead the next dog to the start point to begin its run.

Table 2 presents daily summaries of each dog's performance during HDT-2. Under the column "Daily % of Good Responses" it is apparent that each dog exceeded an 80% performance level at least once during this stage; however, Candy and Sarge showed greater daily variance than Image or Wolf. This is reflected to a greater degree under the column "% of Cumulative Good Responses" which is the ratio of Cumulative Good Responses to Cumulative Number of Targets. Image and Wolf showed a steadily increasing progression throughout HDT-2, while the successive daily percentages of Candy and Sarge varied up and down by several percentage points. This situation is reflected graphically in Figure 3, which shows the learning curves for each dog under HDT-2.

Under the column "Daily Average Distance of Dog to Target" is presented the average ground distance in feet from the dog to the target of all good responses by that dog on the designated day. This average includes those good responses that were visually cued as well as those cued by olfaction, therefore a 40 ft. average distance was the minimum obtainable by any dog since the target would reveal himself when a dog had closed to within 40 ft. of his position.

The intra-dog variance in this data was contributed to by at least two inseparable sources. One was the trial-by-trial wind condition which often varied in direction and strength, particularly in the woods. The other was the learning capacity of each dog as it went about the task of detecting human odor or whatever cues that emanated from a non-visible, silent target. Inter-dog variability, is affected by the dogs' sensory sensitivities which could not be assessed. The distance data, therefore, does not present an unequivocally clear standard for inter-dog comparisons, but it is useful as a general indication of the dogs' performance.

Figure 4 depicts the detection distance data graphically and shows that Wolf responded at longer distances in fewer trials than did the other dogs. Notice that the ordinate begins at 40 ft. which is the minimum average distance at which a dog could respond due to the procedures in use.

The HDT-2 stage could have continued indefinitely by varying the environment of the runs and the techniques of target concealment. Functional objective I.C. (3), however, stated our intention to train each dog to respond to the human stimulus at the maximum distance of which the dog was capable ... , and it was the opinion of the project team that the HDT-2 procedures were not motivating the dogs sufficientlyto encourage them to make truly long range detections. Without extreme food deprivation, for example, there was nothing in the HDT-2 procedures to encourage the dogs to respond immediately to the detected presence of a target. Under the HDT-2 procedures a detection and a response at 200 ft. was no more rewarding than a detection at 200 ft. followed by a response at 40 ft. when the target became visible. To make matters more difficult, there was no absolutely

Table 2: HDT-2 Daily Summaries

Dog	Date	Number of Targets	Cumulative Number of Targets	Number of Target Runs	Number of Good Responses	Daily % of Good Response	Cumulative Good Responses	% of Cumulative Good Responses	
	10-31-68	28	28	6	22	78.6	22	78.6	
	11- 1-68	10	38	2	4	40.0	26	68.4	
Candy	11-4-68	16	54	3	13	81.2	39	72.2	
	11-5-68	15	69	3	7	46.7	46	66.7	
	11-6-68	13	82	3	6	46.2	52	63.4	
	11-7-68	6	88	1	5	83.3	57	64.8	
	10-31-68	20	20	4	14	70.0	14	70.0	
	11- 1-68	10	30	2	10	100.0	24	80.0	
Image	11 -68	16	46	3	13	81.2	37	80.4	
	11- 5-68	8	54	2	8	100.0	45	83.3	
	11-6- 68	14	68	3	12	85.7	57	83.8	
	11- 7-68	6	74	1	6	100.0	63	85.1	
	11- 1-68	10	10	2	6	60.0	6	60.0	
	11- 4-68	16	26	3	13	81.2	19	73.1	
Wolf	11- 5-68	9	35	2	8	88.9	27	77.1	
	11- 6-68	9	44	3	8	88.9	35	79.5	
	11- 7-68	7	51	1	6	85.7	41	80.4	
	11- 1-68	10	10	2	7	70.0	7	70.0	
	11- 4-68	16	26	3	11	68.8	18	69.2	63.
Sarge	11- 5-68	8	34	2	7	87.5	25	73.5	
	11- 6-68	13	47	3	7	53.8	32	68.1	
	11- 7-68	5	52	1	4	80.0	36	69.2	
Group Summary	Σ	265	265	55	197		197		
	$\bar{X}$	66.25	66.25	13.75	49.25		49.25		
	σ^2								
	σ								

Table 2: (continued

Daily Avg. Distance of Dog to Target	Number of Bad Responses	Daily % of Bad Responses	Cumulative Bad Responses	% of Cumulative Bad Responses
53.0	6	21.4	6	21.4
55.0	6	60.0	12	31.6
62.4	3	18.8	15	27.8
74.3	8	53.3	23	33.3
60.8	7	53.8	30	36.6
112.0	1	16.7	31	35.2
*	6	30.0	6	30.0
58.0	0	00.0	6	20.0
42.8	3	18.8	9	19.6
44.0	0	00.0	9	16.7
65.4	2	14.3	11	16.2
96.7	0	00.0	11	14.9
66.7	4	40.0	4	40.0
62.4	3	18.8	7	26.9
120.0	1	11.1	8	22.9
105.6	1	11.1	9	20.5
110.8	1	14.3	10	19.6
53.6	3	30.0	3	30.0
63.5	5	31.2	8	30.8
67.1	1	12.5	9	26.5
91.0	6	46.2	15	31.9
*	1	20.0	16	30.8
	68 17.00		68 17.00	

* no data collected

Figure 3: LEARNING CURVES
HDT-2

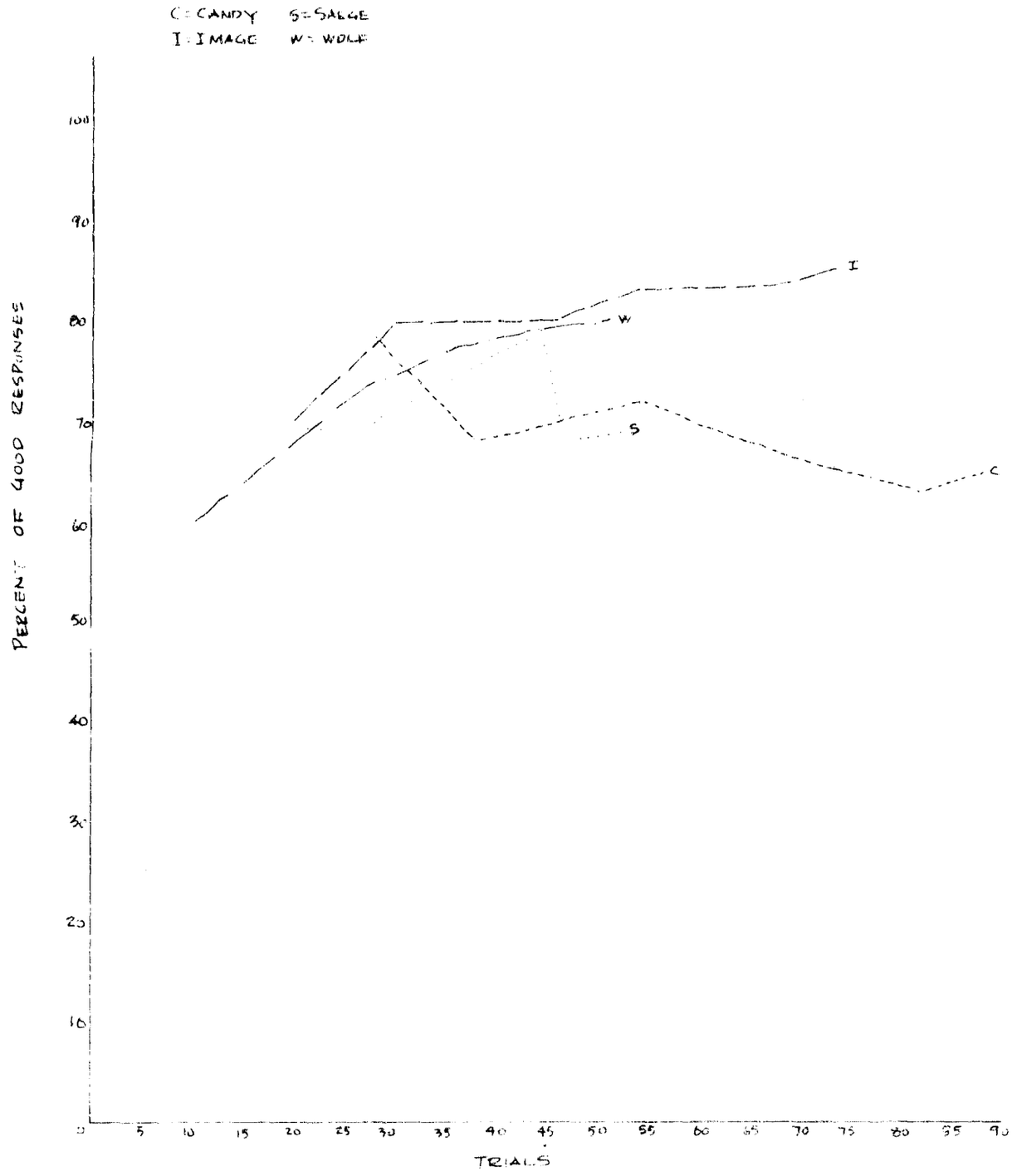
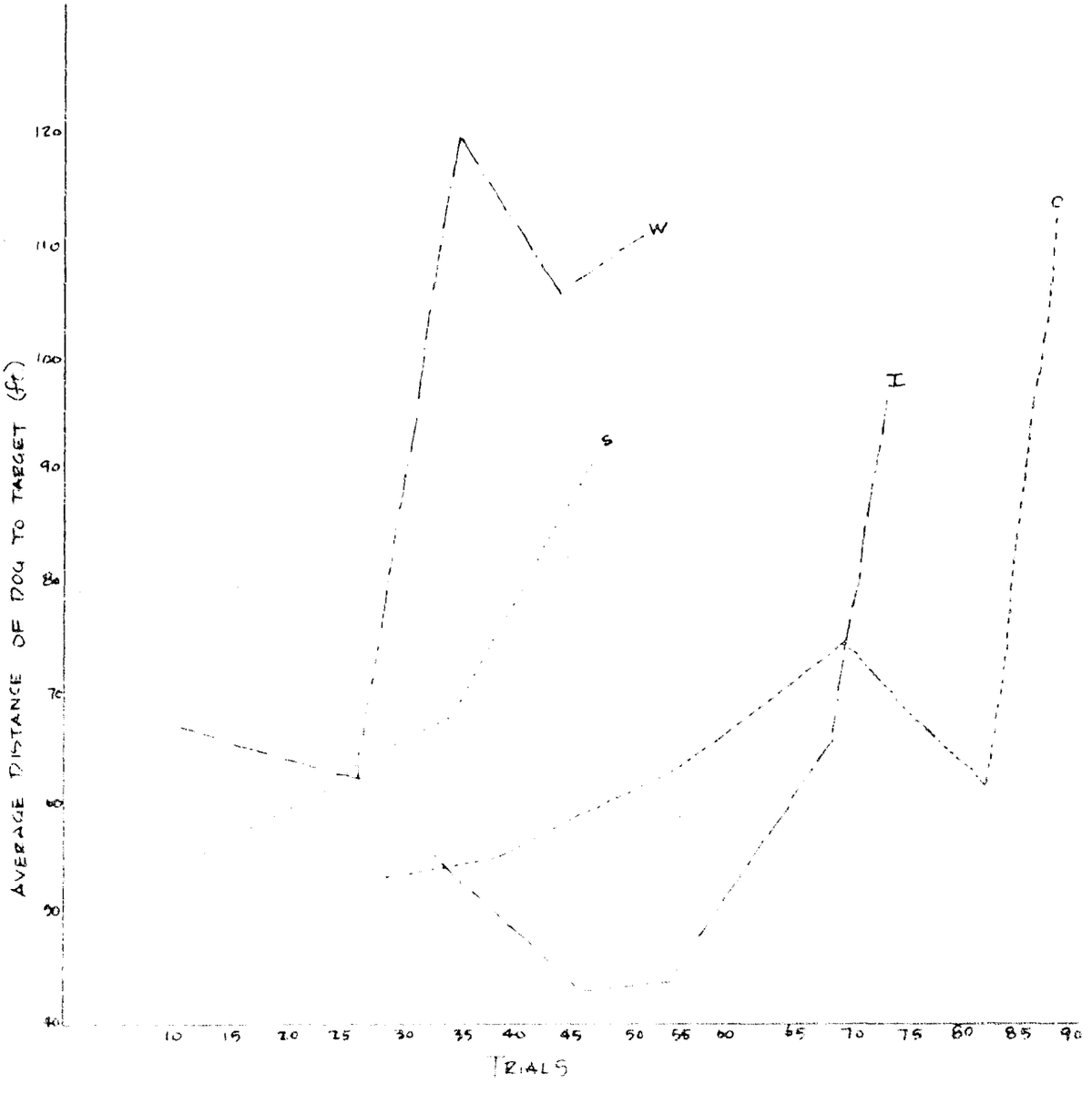


Figure 4: AVERAGE DISTANCE OF DOG TO TARGET IN HDT-2



certain method for ascertaining exactly when a dog detected a target. The detection had to be inferred from the response behavior. If the dog had little incentive to respond at the moment of detection, then the potential of a dog as a human detection mechanism could not be accurately evaluated. Some incentive was required to encourage the coincidence of the detection and the response. HDT-2 was the result of our recognition of this problem.

E. HDT - 2A

The HDT-2A stage was in effect from 11/11/68 to 12/3/68 inclusive, a total of fifteen working days. The purpose of HDT-2A was to maximize the potential for olfactory detection of targets by the dogs through a differential reinforcement procedure. Two general procedural changes also were implemented with the beginning of HDT-2A. One was that no dog would work the same trail more than once in a given week. This was to prevent the dogs from becoming familiar with the hiding places of the targets and responding to trail cues rather than target cues. The second was that all runs were to be conducted with the dog off-leash. The trainer had established strict off-leash obedience control over each dog in advance of HDT-2A so that the dogs could work away from the trainer and remain under his control.

In a typical HDT-2A run, five targets were deployed along a selected woodland trail that had been marked with numbered stakes at 20 ft. intervals. Each target had been assigned a "base" stake number on that trail and was required to conceal himself no less than 10 ft. away from his base stake. The base stakes were at 400 ft. intervals along the trail with the first base stake at least 400 ft. from the start point of the run.

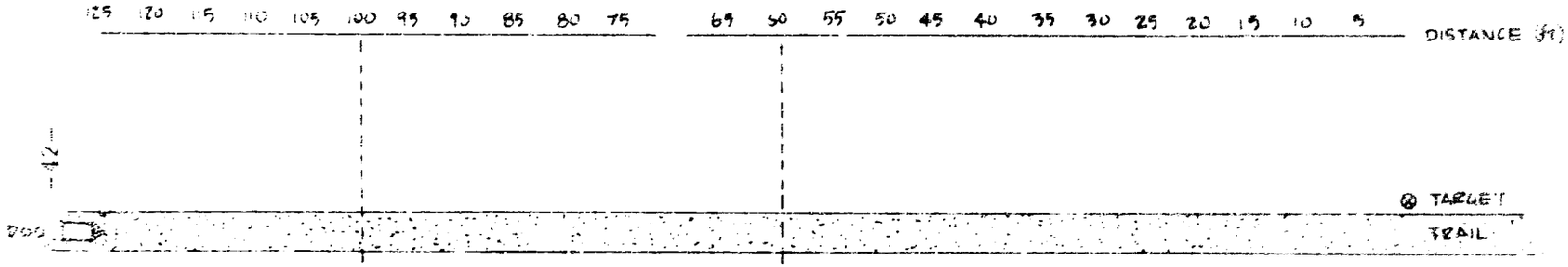
The subject dog was brought from the stake-out area to the start point of its run and was harnessed. A command to move out marked the beginning of the run and the first trial.

Each trial in a given run encompassed three possibilities of response from the dog. Figure 5 shows these schematically.

In the first nine days of HDT-2A, if the dog responded at a distance from the target in excess of 100 ft., it was assumed that the stimulus cue was olfactory. If the dog had not responded when it had closed to within 100 ft. of the target, the target gave an auditory cue by vigorously clapping his hands no more than three times in rapid succession. If the dog failed to respond to the auditory cue and continued to close on the target, at a distance of 60 ft. the target quickly moved from his concealment to become visible to the dog. If the dog failed to respond to this visual cue within five seconds, the handler would force the dog into the down position.

In order to provide incentive for the dogs to respond immediately to olfactory cues, the above response possibilities were differentially reinforced. If the dog responded to an assumed olfactory cue (i.e., in excess of 100 ft. from the target), it was reinforced with the quantity of "X" of Prime allotted to that trial, praise and petting, and a given quantity of what was called a "Super Incentive reward." This reinforcement combination was abbreviated as TOP, standing for "Total Olfactory Performance."

Figure 5: HDT-2A Response Possibilities and Reinforcement Contingencies



TOP
Assumed olfactory cue Reinforcement: Prime, Praise & Petting, and the Super Incentive Reward

PAR
Auditory cue at 100 feet Reinforcement: Prime, Praise & Petting

POR
Visual-Auditory cues at 60 feet Reinforcement: Praise & Petting If no response, dog is forced down and given no reinforcement

If the dog responded to an auditory cue, it was reinforced with the quantity "X" of Prime allotted to that trial and praise and petting, but no super incentive. This reinforcement combination was abbreviated as PAR, standing for "Prime Auditory Reward."

If the dog responded to the visual cue, it was reinforced only with praise and petting. This reinforcement was abbreviated as POR, standing for "Praise Only Reward."

If the dog failed to respond to any cue and had to be forced into the down position, no reinforcement of any type was given.

On a given trial only one type of response was possible. When the dog responded, either TOP or PAR, the target revealed himself, then ran at least 300 ft. to the downwind side of the dog and resumed hiding while the dog was being reinforced. With a POR response or a correction by the handler, the target was already revealed and would run away as soon as the dog was down. After waiting in concealment for at least 10 minutes the target would work his way back to his base stake cautiously and wait in concealment for the next dog.

A given trial ended with a command to move out after the dog had been reinforced or corrected. The run ended only when the dog was returned to the stake-out area, unharnessed, and given a break period. The dog was not permitted to quit working while in harness, even after the last target in the run had been contacted.

The super incentive reward embodied in TOP situations was difficult to establish. It had to be something decidedly more appealing to the dogs than Prime, but also non-filling so that it would not interfere with the dogs' intake of Prime which was their basic diet. Simple preference tests conducted with kennelled, non-project German Shepherds allowed us to eliminate several possibilities. Three possibilities for a super incentive survived the preference tests and were field tested. The first was small-dog size Milk Bone Dog Biscuits upon each of which has been placed three drops of Sucaryl, a 50% saccharin solution in a water base. This was rejected for field use because the treated biscuits would increase a dog's thirst to the point that it would bloat itself with water when returned to the stake-out area. One inch cubes of roast beef were rejected also after field trials revealed them to be too inconvenient to handle. The super incentive that passed both preference and field tests was boiled, one-half inch slices of hot dog, which became the super incentive in HDT-2A.

In the first nine days of HDT-2A, the dog to target distance at which the auditory cue was given by the targets was 100 ft. This arbitrary distance was selected for several reasons. The distance could not be so great that the dogs would have no chance of detecting the target olfactorally before the auditory cue was given. The dogs could learn the difference between TOP and PAR only through having the opportunity to make responses under both reinforcement contingencies. In the final runs under HDT-2, the dogs were averaging approximately 100 ft. per detection, therefore we could anticipate that the dogs would respond to the targets at distances greater than 100 ft. on roughly 50% of their initial trials under HDT-2A. On the other 50% of their initial trials the dogs would encounter the auditory cue. Environmental factors also entered into the decision

to set the auditory cue distance at 100 ft. The winter weather was killing the underbrush in the woods, making it increasingly difficult for the targets to maintain complete concealment from the dogs, particularly when they were in motion, such as in clapping their hands. The greater the distance that the dog was from the target, the less its chance was of accidentally seeing such movements.

Later in HDT-2A, when the dogs were averaging approximately 200 ft. per olfactory detection, it was decided to increase the difficulty of earning TOP by increasing to 200 ft. the dog to target distance at which the auditory cue was given. Under the general assumption that the strength of olfactory cues decreased with increasing distance of the auditory cue, the dog would have to make its response decision on the basis of correspondingly less sensory information in order to earn TOP.

The procedures developed for HDT-2A could have had one very undesirable effect if it had not been anticipated. This was the problem of false positive responses. The reinforcement structure of HDT-2A was biased in favor of the olfactory detection of targets by a dog. On an HDT-2A run with targets on the trail, if a dog responded anywhere on the trail between its last contact and before the next target gave his auditory cue, it was rewarded with TOP, as if it had actually detected the next target olfactorally. As a point of fact, it never was possible to determine with absolute certainty the stimulus to which a dog was responding. When a dog responded in proximity to a target, the response had to be treated as if it was target cued, whether or not the dog had actually detected the target. If a response was reinforced when the dog had not detected a target, the dog could have learned to respond with random down responses that were unrelated entirely to the presence of a target.

This undesirable possibility that could have developed in HDT-2A was countered with two techniques. One was to run the dogs on clean trails containing no targets. A response on such a trail was not reinforced. A second technique was to run the dogs on long trails containing one target placed approximately in the middle of the run. The critical issue here was to see if the dogs could detect the single target without giving false positive responses after the single contact. With either of these techniques, all other procedures employed were the same as those used on regular target runs to prevent the dogs from learning a discrimination between regular target runs and the zero or one target runs. It was the opinion of the project team that if the dogs gave very few or no false positive responses on the special runs, this could be taken as evidence that the dogs actually were responding to the targets on regular runs. No other reasonable explanation could account for the observed behavior across all runs.

Table 3 presents daily summaries of each dog's performance during HDT-2A. Three of the dogs were worked a full fifteen days, while the fourth dog, Sarge, was worked only nine days during this training stage because he contracted a severe interdigital foot infection that made walking obviously painful to him. Sarge was dropped from the HDT project on 12/2/68 because of this disability.

Due to space limitations the following table (Table 3) is divided on the next six pages, and is assembled as the legend below indicates.

p.46-Part a	p.47-Part b	p.48-Part c
p.49-Part d	p.50-Part e	p.51-Part f

Table 3: HDT-2A Daily Summaries (Part a)

Dog	Date	Number of Targets	Cumulative No. of Targets	Number of Target Runs	No. of Good Responses	Daily % of Good Responses	Cumulative Good Responses	% of Cumulative Good Responses	Daily Avg. Dist. Dog to Target
	11-11-68	10	10	2	8	80.0	8	80.0	102.5
	11-12-68	10	20	2	7	70.0	15	75.0	131.4
	11-13-68	21	41	4	18	85.7	33	80.5	81.5
	11-14-68	5	46	1	3	60.0	36	78.3	100.0
	11-15-68	10	56	2	6	60.0	42	75.0	146.7
	11-18-68	23	79	4	19	82.6	61	77.2	139.1
	11-19-68	19	98	4	19	100.0	80	81.6	138.7
Candy	11-20-68	12	110	2	12	100.0	92	83.6	191.7
	11-21-68	10	120	2	8	80.0	100	83.3	171.3
	11-22-68	12	132	2	12	100.0	112	84.8	259.6
	11-25-68	14	146	3	14	100.0	126	86.3	236.4
	11-26-68	7	153	2	7	100.0	133	86.9	151.4
	11-27-68	5	158	1	5	100.0	138	87.3	224.0
	12- 2-68	10	168	2	9	90.0	147	87.5	199.4
	12- 3-68	7	175	1	7	100.0	154	88.0	294.3
	11-11-68	10	10	2	9	90.0	9	90.0	107.8
	11-12-68	10	20	2	8	80.0	17	85.0	80.0
	11-13-68	24	44	4	24	100.0	41	93.2	100.0
	11-14-68	7	51	1	7	100.0	48	94.1	109.1
	11-15-68	11	62	2	10	90.9	58	93.5	104.0
	11-18-68	15	77	3	15	100.0	73	94.8	126.0
	11-19-68	25	102	5	25	100.0	98	96.1	123.6
Image	11-20-68	11	113	2	10	90.9	108	95.6	166.5
	11-21-68	11	124	2	10	90.9	118	95.2	145.5
	11-22-68	12	136	2	11	91.7	129	94.9	255.9
	11-25-68	9	145	2	8	88.9	137	94.5	274.4
	11-26-68	4	149	1	4	100.0	141	94.6	225.0
	11-27-68	5	154	1	5	100.0	146	94.8	264.0
	12- 2-68	14	168	2	14	100.0	160	95.2	216.8
	12- 3-68	5	173	1	5	100.0	165	95.4	214.0

Table 3: HDT-2A Daily Summaries (continued) (Part b)

Number of Bad Responses	Daily % of Bad Responses	Cumulative Bad Responses	% Cumulative Bad Responses	Number of TOP Responses	% of TOP Responses	Cumulative TOP Responses	% of Cumulative TOP Responses
2	20.0	2	20.0	3	30.0	3	30.0
3	30.0	5	25.0	1	10.0	4	20.0
3	14.3	8	19.5	4	19.0	8	19.5
2	40.0	10	21.7	1	20.0	9	19.6
4	40.0	14	25.0	2	20.0	11	19.6
4	17.4	18	22.8	11	47.8	22	27.8
0	00.0	18	18.4	11	57.9	33	33.7
0	00.0	18	16.4	8	66.7	41	37.3
2	20.0	20	16.7	4	40.0	45	37.5
0	00.0	20	15.2	6	50.0	51	38.6
0	00.0	20	13.7	8	57.1	59	40.4
0	00.0	20	13.1	4	57.1	63	41.2
0	00.0	20	12.7	3	60.0	66	41.8
1	10.0	21	12.5	4	40.0	70	41.7
0	00.0	21	12.0	6	85.7	76	43.4
1	10.0	1	10.0	2	20.0	2	20.0
2	20.0	3	15.0	3	30.0	5	25.0
0	00.0	3	6.8	8	33.3	13	29.5
0	00.0	3	5.9	3	42.9	16	31.4
1	9.1	4	6.5	4	36.4	20	32.3
0	00.0	4	5.2	4	26.7	24	31.2
0	00.0	4	3.9	10	40.0	34	33.3
1	9.1	5	4.4	7	63.6	41	36.3
1	9.1	6	4.8	5	45.5	46	37.1
1	8.3	7	5.1	7	58.3	53	39.0
1	11.1	8	5.5	6	66.7	59	40.7
0	00.0	8	5.4	2	50.0	61	40.9
0	00.0	8	5.2	4	80.0	65	42.2
0	00.0	8	4.8	5	35.7	70	41.7
0	00.0	8	4.6	2	40.0	72	41.6

Table 3: HDT-2A Daily Summaries (continued) (Part c)

TOP Daily Avg Distance Dog to Target	Miss	False Positive	
			Auditory
140.0			cue 100'
400.0			
132.5			
140.0			
275.0			
175.5			
185.0			
243.8			
242.5			
365.8			Auditory cue 200'
322.5			
210.0			
253.3			
252.5			
310.0			
240.0			Auditory cue 100'
166.7			
137.5			
121.3			
130.0			
217.5			
187.0			
206.4			
202.0			
316.4			
345.8			
320.0			
280.0			
267.0			
350.0			

Table 3: HDT-2A Daily Summaries (continued) (Part d)

Dog	Date	Number of Targets	Cumulative No.of Targets	Number of Target Runs	No. of Good Responses	Daily % of Good Responses	Cumulative Good Responses	% of Cumulative Good Responses	Daily Avg. Dist. Dog to Target
	11-11-68	10	10	2	6	60.0	6	60.0	170.0
	11-12-68	10	20	2	6	60.0	12	60.0	120.0
	11-13-68	25	45	4	20	80.0	32	71.1	138.5
	11-14-68	7	52	1	7	100.0	39	75.0	140.7
	11-15-68	11	63	2	9	81.8	48	76.2	125.5
	11-18-68	22	85	4	18	81.8	66	77.6	132.5
	11-19-68	18	103	3	17	94.4	83	80.6	112.9
Wolf	11-20-68	12	115	2	11	91.7	94	81.7	146.4
	11-21-68	11	126	2	9	81.8	103	81.7	170.5
	11-22-68	11	137	2	11	100.0	114	83.2	239.5
	11-25-68	15	152	3	15	100.0	129	84.9	278.3
	11-26-68	5	157	1	5	100.0	134	85.4	202.0
	11-27-68	7	164	1	7	100.0	141	86.0	221.4
	12- 2-68	10	174	2	8	80.0	149	85.6	172.5
	12- 3-68	6	180	1	5	83.3	154	85.6	204.0
	11-11-68	10	10	2	8	80.0	8	80.0	79.4
	11-12-68	8	18	2	5	62.5	13	72.2	112.0
	11-13-68	23	41	4	20	87.0	33	80.5	91.0
	11-14-68	5	46	1	4	80.0	37	80.4	117.5
	11-15-68	11	57	2	7	63.6	44	77.2	130.7
	11-20-68	12	69	2	12	100.0	56	81.2	203.8
	11-21-68	11	80	2	8	72.7	64	80.0	145.0
Sarge	11-22-68	11	91	2	11	100.0	75	82.4	264.1
	12- 2-68	6	97	1	5	83.3	80	82.5	207.0

Table 3: HDT-2A Daily Summaries (continued) (Part e)

Number of Bad Responses	Daily % of Bad Responses	Cumulative Bad Responses	% Cumulative Bad Responses	Number of TOP Responses	% of TOP Responses	Cumulative TOP Responses	% of Cumulative TOP Responses
4	40.0	4	40.0	5	50.0	5	50.0
4	40.0	8	40.0	4	40.0	9	45.0
5	20.0	13	28.9	10	40.0	19	42.2
0	00.0	13	25.0	6	85.7	25	48.1
2	18.2	15	23.8	3	27.3	28	44.4
4	18.2	19	22.4	9	40.9	37	43.5
1	5.6	20	19.4	6	33.3	43	41.7
1	8.3	21	18.3	7	58.3	50	43.5
2	18.2	23	18.3	6	54.5	56	44.4
0	00.0	23	16.8	6	54.5	62	45.3
0	00.0	23	15.1	11	73.3	73	48.0
0	00.0	23	14.6	3	60.0	76	48.4
0	00.0	23	14.0	2	28.6	78	47.6
2	20.0	25	14.4	1	10.0	79	45.4
1	16.7	26	14.4	3	50.0	82	45.5
2	20.0	2	20.0	1	10.0	1	10.0
3	37.5	5	27.8	2	25.0	3	16.7
3	13.0	8	19.5	6	26.1	9	22.0
1	20.0	9	19.6	2	40.0	11	23.9
4	36.4	13	22.8	3	27.3	14	24.6
0	00.0	13	18.8	9	75.0	23	33.3
3	27.3	16	20.0	5	45.5	28	35.0
0	00.0	16	17.6	6	54.5	34	37.4
1	16.7	17	17.5	3	50.0	37	38.1

Table 3: HDT-2A Daily Summaries (continued) Part f)

TOP Daily Avg Distance Dog to Target	Miss	False Positive	
188.0			Auditory cue 100'
140.0			
177.0			
154.2			
213.3		1	
163.9			
151.7			
190.7			
212.5			
315.8			Auditory cue 200'
306.8			
270.0			
265.0			
500.0			
206.7		1	
120.0			Auditory cue 100'
170.0			
120.0			
135.0			
171.7			
250.5			
180.0			
358.3			Auditory cue 200'
211.7			

The columns in this table dealing with good responses include all TOP, PAR, and POR responses as a group since they were all voluntary down responses even though cued differently.

The entries in column "% of Cumulative Good Responses" represent the ratio of the Cumulative Good Responses to Cumulative Number of Targets for any given day. Figure 6 was constructed from these percentages. It displays graphically the learning curves for each dog during HDT-2A. These curves make it evident that the dogs were approaching an asymptote in their response levels. The response level of Image was particularly high because she seldom failed to respond to a suddenly visible target.

Under the column "Daily Average Distance of Dog to Target" is entered the average of the ground distance in feet from the dog to the target for all good responses by the given dog for the designated day. This daily average includes all TOP, PAR, and POR good responses. Figure 7 was constructed from these average distances. It reveals that even with daily fluctuations in performance, all dogs exhibited a generally increasing average detection distance across HDT-2A.

The purpose of HDT-2A was to maximize the potential for olfactory detection of targets by the dogs, therefore, the data concerned with the TOP situations was of particular interest. Five columns in Table 3 present TOP data. The column "% of TOP Responses" presents the daily ratio of the Number of TOP Responses to the Number of Targets, which is the daily percentage of olfactory detections per daily total of opportunities for such detections. These percentages vary widely from day to day, and although no correlational data is available to support this contention, much of this variance was contributed to by the changing daily wind conditions.

The entries in the column "% of Cumulative TOP Responses," which are the daily ratios of the Cumulative TOP Responses to the Cumulative Number of Targets, absorb this variance somewhat and show that across HDT-2A each dog was detecting targets olfactorally approximately 40% of the time.

The entries in the column "TOP Daily Average Distance of Dog to Target" are the averaged ground distances in feet from the dog to the target for all olfactory detections by a given dog on the designated day. The theoretical minimum obtainable average in this column was 100 ft. during the first nine days of HDT-2A because that was the distance of the auditory cue for PAR. On the last six days of HDT-2A this minimum obtainable average shifted to 200 ft. As can be seen, each dog had at least one day's performance where its average reached or exceeded 350 ft., an average olfactory detection of well over 100 yards per target. Figure 8 displays this data graphically.

There were no misses during HDT-2A since the procedures would always bring the dogs into contact with the deployed targets. A failure to respond in the TOP or PAR situations was not regarded as a bad response or a miss. In the TOP situation there was no possibility of determining a miss with any certainty. The only bad response that could have been recorded was an improperly postured response which just did not occur during HDT-2A.

Figure 6: -53- LEARNING CURVES
HDT-2A

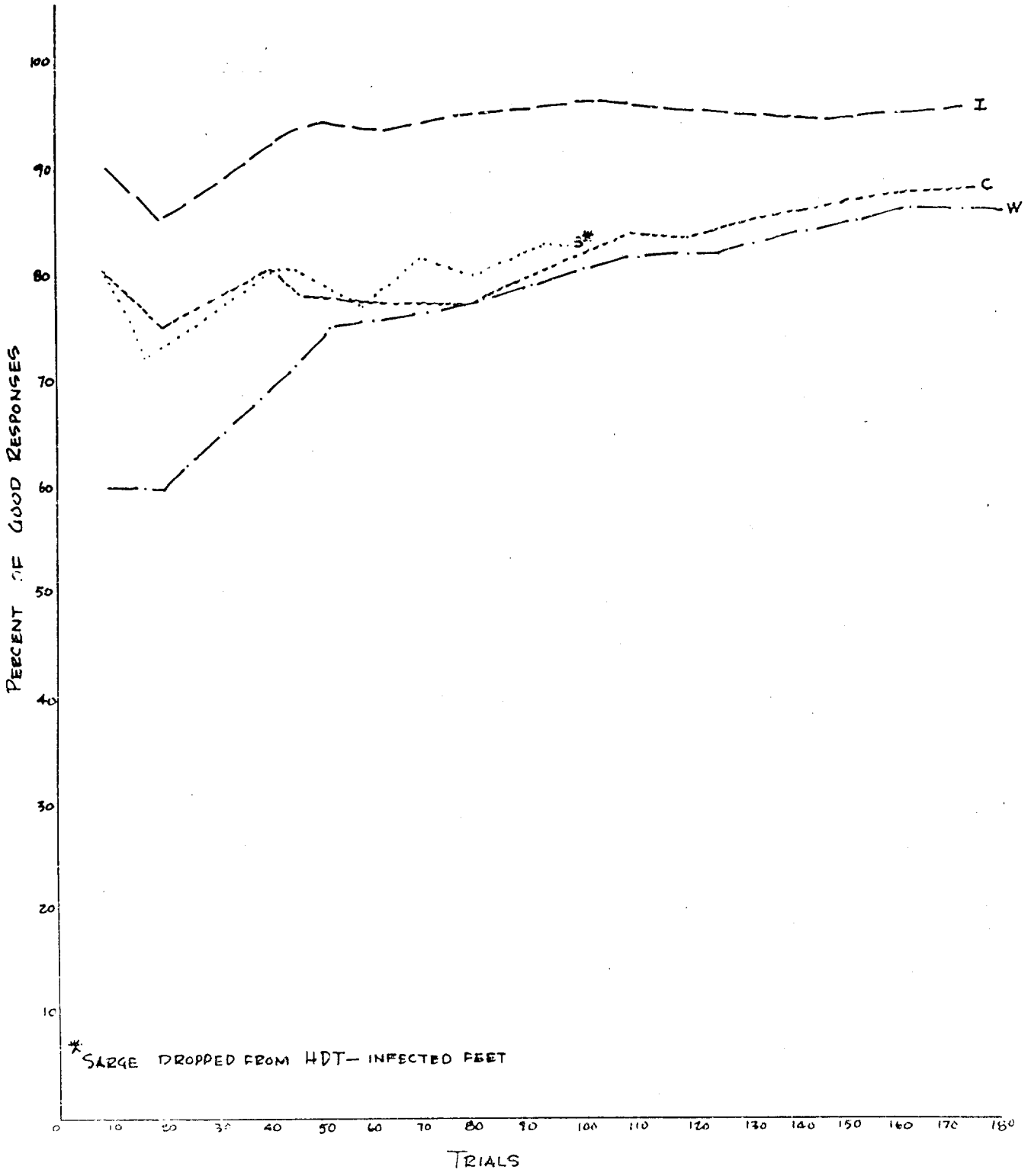


Figure 7: -54- AVERAGE DISTANCE OF DOG TO TARGET IN HDT-2A FOR ALL GOOD RESPONSES

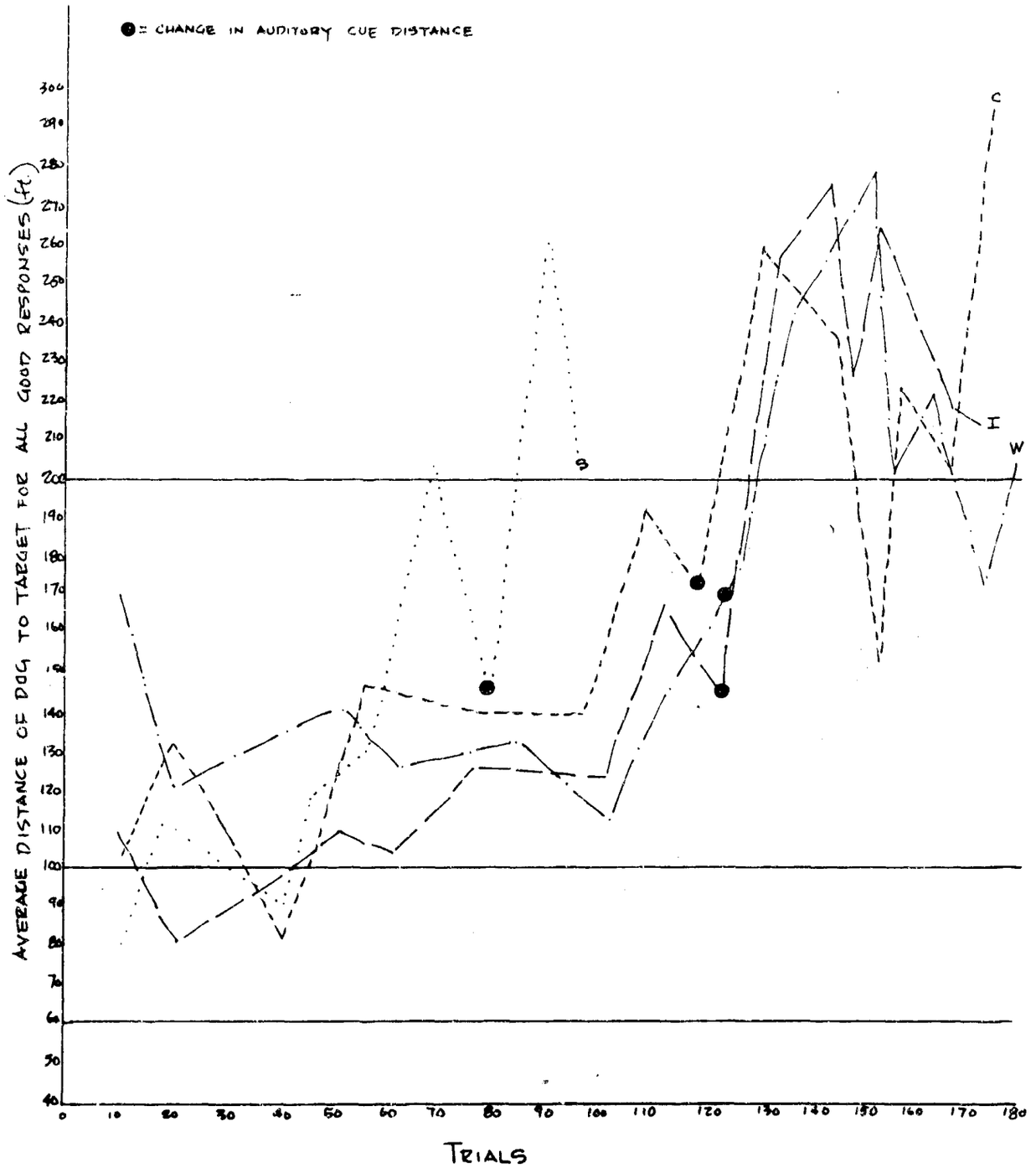
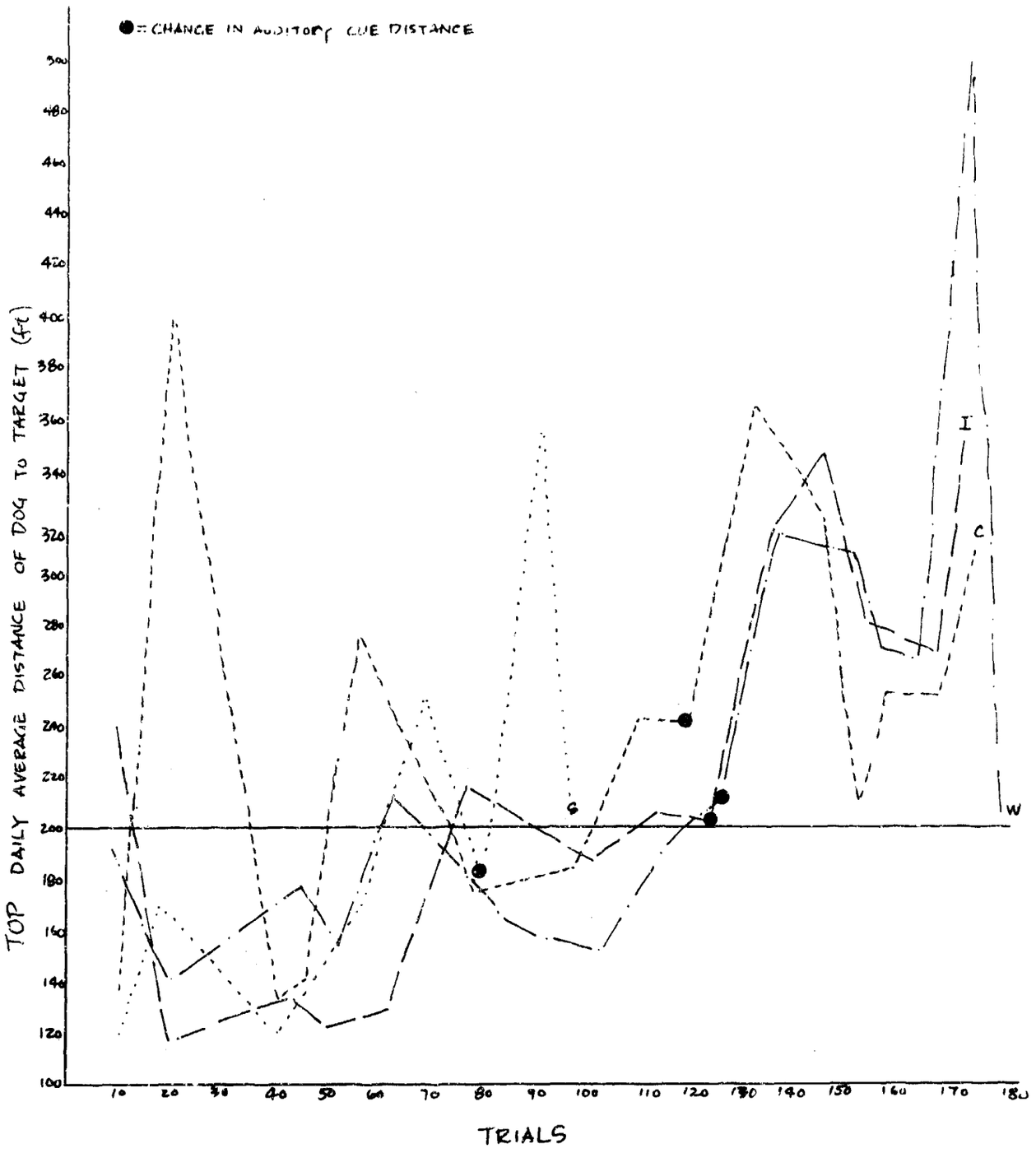


Figure 8: AVERAGE DISTANCE OF DOG TO TARGET IN HDT-2A FOR TOP (Total Olfactory Performance)



In the PAR situation either a bad response or a miss could have been recorded. Two factors weighed against this interpretation of the dogs' behavior.

The first factor was that there was no way to teach the dog that ignoring the auditory cue was a bad response without eliminating the POR situation entirely. If, for example, the dog was corrected for failing to respond to the auditory cue, the target would have had to move away from the trail to avoid having the dog respond a second time on the same target. Without the POR situation, however, it was possible that the dogs would have begun to extinguish their response to a visible target, which, in fact, possibly did occur in HDT-2A[1] discussed below.

A second factor was that the handler would have had to interpret each PAR situation to determine whether or not the dog had heard the auditory cue. Quite often, with a strong wind blowing in the woods, the auditory cue was not audible to the human ear. In such situations the handler would have been forced to decide whether or not an auditory cue had been given by the target, and whether or not his dog, with its more sensitive hearing, had heard an auditory cue. A wrong decision by the handler would have damaged the intended training by some inestimable amount. It was decided, therefore, not to record a failure to respond as a bad response or miss in the TOP or PAR situations, but to continue to record such behavior as a bad response in the POR situation.

Only Wolf made any false positive responses during HDT-2A. There was no observable explanation for this phenomenon, particularly in light of the dogs' later performances in HDT-2A[1], when they each made several false positive responses. The data for HDT-2A supports the conclusion that the dogs were performing exactly as had been hoped. That is, the dogs were responding to targets when targets were present and were not responding when targets were absent.

Throughout HDT-2A the changing winds were a source of continual frustration. It was not possible to obtain an accurate estimation of the dog's olfactory capabilities when on one trial a strong wind was moving from the target to the dog and on the very next trial the wind had increased or decreased in strength. In the woods this problem was compounded because the trees would break-up wind currents into numerous eddies that would place the dog and the target in two different wind patterns. It was decided, therefore, that the next stage of training was to attempt to discover the dogs' maximum range of olfactory detection capabilities, as well as to expose them to a field situation in which their probable deployment was quite likely. The HDT-2A[1] stage was the result of this decision.

F. HDT - 2A[1]

The HDT-2A[1] stage was in effect from 12/4/68 to 12/19/68 inclusive, a total of twelve working days. The purpose of HDT-2A[1] was to expose the dogs to the field situation of targets concealed along roadways and other open terrain where a maximum possible detection distance was critical for the safety of the dog and handler. The HDT-2A[1] runs were conducted either on the county maintained, unimproved secondary roads of Wake County or the adjoining Harnett and Chatham

counties or on a few large plots of open terrain near the BSI field station such as acreage cleared for seedling forests by the Weyerhauser Paper Corp.

The training runs for each dog under HDT-2A[1] were a mixture of runs with targets and runs without targets. Each target run contained no planned targets. In either type of run, occasional unplanned targets appeared such as farmers, hunters, a game warden, children, and curious people in vehicles would stop. These accidental contacts were regarded as target contacts since the dogs should have responded to them and, in most instances, they did respond to these people. The no-target runs were of two types. In one type the dog run was over an area where the dog previously had not been run. The other type of no-target run was a dog run over an area where the dog previously had been run within the same day. Except for this latter type of no-target run, every run conducted under HDT-2A[1] was over an area where none of the dogs previously had been worked. No dog run during HDT-2A[1] was less than one mile in length.

In a typical HDT-2A[1] target run, the road chosen was at least one mile long, relatively free of farms and houses, and oriented such that the dog would be working as much as possible into the prevailing wind. The number of targets available for the run were deployed in equal-distance intervals across the run with one constraint. No two targets were closer together than three-tenths of a mile. With five targets deployed individually this required a run of at least one and one-half miles since the start point for the dog was at least three-tenths of a mile from the nearest target.

When the targets were deployed, the handler, who was at the start point, was called by radio to begin the run. A command to the dog to move out marked the beginning of the run and the first trial. During the run the dog was encouraged to move out far in front of the handler. Wolf and Image usually would work between 150 and 250 yards in front of the handler, while Candy usually worked about 100 yards in front of the handler.

The auditory cue was dropped from HDT-2A[1] entirely, and from the second day to the end of HDT-2A[1] each target was instructed to stay concealed and not to reveal himself unless the dog was at least of his position or unless he was instructed by radio to reveal himself because the dog had detected him. It was our intention that only olfactory cues were to be available to the dog, unless the dog was about to go past a concealed target, in which case the target would present the visual cue.

If the dog responded to a target before that target revealed himself, the response was recorded as TOP and was reinforced by the handler in exactly the same manner as a TOP response in HDT-2A. A response that was visually cued was recorded as POR and was reinforced as in HDT-2A. A few of the accidental contacts and one or two target errors caused the dogs to respond to an auditory cue before the target was visible. These were recorded as PAR responses and also were reinforced as in HDT-2A.

Due to space limitations the following table (Table 4) is divided on the next six pages, and is assembled as the legend below indicates.

p.59-Part a	p.60-Part b	p.61-Part c
p.62-Part d	p.63-Part e	p.62-Part f

Table 4: HDT-2A[1] Daily Summaries (Part a)

Dog	Date	Number of Targets	Cumulative No. Targets	Number of Target Runs	No. of Good Responses	Daily % of Good Responses	Cumulative Good Responses	% of Cumulative Good Responses	Daily Avg. Dist. Dog to Target
	12- 4-68	4	4	1	4	100.0	4	100.0	53.8
	12- 5-68	2	6	1	2	100.0	6	100.0	60.0
	12- 6-68	5	11	1	4	80.0	10	90.9	66.3
	12- 9-68	9	20	2	5	55.6	15	75.0	98.0
	12-10-68	9	29	2	6	66.7	21	72.4	258.8
	12-11-68	9	38	2	6	66.7	27	71.1	128.3
Candy	12-12-68	9	47	2	4	44.4	31	66.0	168.8
	12-13-68	1	48	1	1	100.0	32	66.7	200.0
	12-16-68	5	53	1	5	100.0	37	69.8	145.0
	12-17-68	1	54	1	1	100.0	38	70.4	100.0
	12-18-68	4	58	2	3	75.0	41	70.7	218.3
	12-19-68	7	65	2	7	100.0	48	73.8	255.0
	12- 4-68	5	5	1	5	100.0	5	100.0	123.0
	12- 6-68	6	11	2	6	100.0	11	100.0	43.3
	12- 9-68	9	20	2	7	77.8	18	90.0	91.4
	12-10-68	9	29	2	9	100.0	27	93.1	110.0
	12-11-68	10	39	2	6	60.0	33	84.6	165.0
Image	12-12-68	9	48	2	9	100.0	42	87.5	465.1
	12-13-68	3	51	2	3	100.0	45	88.2	223.3
	12-16-68	5	56	1	5	100.0	50	89.3	419.4
	12-17-68	1	57	1	1	100.0	51	89.5	80.0
	12-18-68	2	59	1	0	00.0	51	86.4	00.0
	12-19-68	5	64	1	3	60.0	54	84.4	90.0

Table 4: HDT-2A[1] Daily Summaries (continued) (Part b)

Number of Bad Responses	Daily % of Bad Responses	Cumulative Bad Responses	% Cumulative Bad Responses	Number of TOP Responses	% of TOP Responses	Cumulative TOP Responses	% Cumulative TOP Responses
0	00.0	0	00.0	0	00.0	0	00.0
0	00.0	0	00.0	0	00.0	0	00.0
1	20.0	1	9.1	1	20.0	1	9.1
4	44.4	5	25.0	2	22.2	3	15.0
3	33.3	8	27.6	6	66.7	9	31.0
3	33.3	11	28.9	5	55.6	14	36.8
5	55.6	16	34.0	4	44.5	18	38.3
0	00.0	16	33.3	1	100.0	19	39.6
0	00.0	16	30.2	4	80.0	23	43.4
0	00.0	16	29.6	1	100.0	24	44.4
1	25.0	17	29.3	1	25.0	25	43.1
0	00.0	17	26.2	5	71.4	30	46.2
0	00.0	0	00.0	3	60.0	3	60.0
0	00.0	0	00.0	1	16.7	4	36.4
2	22.2	2	10.0	4	44.4	8	40.0
0	00.0	2	6.9	4	44.4	12	41.4
4	40.0	6	15.4	4	40.0	16	41.0
0	00.0	6	12.5	9	100.0	25	52.1
0	00.0	6	11.8	2	66.7	27	52.9
0	00.0	6	10.7	4	80.0	31	55.4
0	00.0	6	10.5	0	00.0	31	54.4
2	100.0	8	13.6	0	00.0	31	52.5
2	40.0	10	15.6	2	40.0	33	51.6

Table 4: HDT-2A[1] Daily Summaries (continued) (Part c)

TOP Daily Avg Distance Dog to Target	Daily Maximum TOP Distance	False Positive	Clean Trail Runs
00.0	-		
00.0	-	1	1
85.0	85		1
147.5	175		
258.8	963		
146.0	225		
168.8	280		
200.0	200	2	1
173.8	240		1
100.0	100		1
275.0	275	2	1
286.0	370		1
181.7	300		1
30.0	30	1	
130.0	150		
167.5	330		
220.0	300		
465.1	1161		
305.0	500	5	1
511.8	813	1	1
00.0	-		1
00.0	-	2	1
115.0	170		1

Table 4: HDT-2A[1] Daily Summaries (Part d)

Dog	Date	Number of Targets	Cumulative No. Targets	Number of Target Runs	No. of Good Responses	Daily % of Good Responses	Cumulative Good Responses	% of Cumulative Good Responses	Daily Avg. Dist. Dog to Target
	12- 4-68	4	4	1	2	50.0	2	50.0	72.5
	12- 5-68	4	8	1	4	100.0	6	75.0	110.0
	12- 6-68	10	18	2	7	70.0	13	72.2	122.1
	12- 9-68	12	30	3	9	75.0	22	73.3	318.1
	12-10-68	9	39	2	6	66.7	28	71.8	195.0
	12-11-68	9	48	2	9	100.0	37	77.1	137.2
Wolf	12-12-68	11	59	2	7	63.6	44	74.6	171.4
	12-13-68	3	62	1	3	100.0	47	75.8	206.7
	12-16-68	6	68	1	3	50.0	50	73.5	116.7
	12-17-68	1	69	1	1	100.0	51	73.9	60.0
	12-18-68	1	70	1	1	100.0	52	74.3	60.0
	12-19-68	5	75	1	3	60.0	55	73.3	155.0

Table 4: HDT-2A[1] Daily Summaries (continued) (Part e)

Number of Bad Responses	Daily % of Bad Responses	Cumulative Bad Responses	% Cumulative Bad Responses	Number of TOP Responses	% of TOP Responses	Cumulative TOP Responses	% Cumulative TOP Responses
2	50.0	2	50.0	1	25.0	1	25.0
0	00.0	2	25.0	2	50.0	3	37.5
3	30.0	5	27.8	4	40.0	7	38.9
3	25.0	8	26.7	8	66.7	15	50.0
3	33.3	11	28.2	6	66.7	21	53.8
0	00.0	11	22.9	6	66.7	27	56.3
4	30.4	15	25.4	6	54.5	33	55.9
0	00.0	15	24.2	1	33.3	34	54.8
3	50.0	18	26.5	2	33.3	36	52.9
0	00.0	18	26.1	1	100.0	37	53.6
0	00.0	18	25.7	0	00.0	37	52.9
2	40.0	20	26.7	2	40.0	39	52.0

Table 4: HDT-2A[1] Daily Summaries (continued) (Part f)

TOP Daily Avg Distance Dog to Target	Daily Maximum TOP Distance	False Positive	Clean Trail Runs
85.0	85		
187.5	200	1	1
187.5	250		
350.4	885	1	
195.0	525		
183.3	310		
190.0	300		
500.0	500	3	1
145.0	195		1
60.0	60		1
00.0	-		1
202.5	345		1

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13. ABSTRACT

Reports from the field indicated that German Shepherd scout dogs has been observed to alert on mines, tripwires and other man-made artifacts. The purpose of the following program was to explore the feasibility of training such animals specifically to the tasks of detecting mine/tripwires and tunnels, by means of techniques that were sufficiently objective to permit instruction of military handlers in their use.

A six month feasibility study was conducted at the Vehavior Systems, Incorporated Research Station in Raleigh, North Carolina. Procedures and practices derived from the formal study of animal behavior were used throughout the program. Feasibility was established as a result of a demonstration while at Fort Gordon, Georgia on July 18, 1968. For details of the demonstration, see Appendix A.

Because of the success of this first phase of the problem, a second six months of work was initiated with the objective of training an army scout dog platoon for the capability of mine/tripwire and tunnel detection. This work was conducted at Fort Gordon, Ga., using essentially the same techniques as those developed during the feasibility study. The platoon was judged ready and deployed to Vietnam, April 20, 1969.

An additional three month program was undertaken to study the feasibility of cross-training tunnel and personnel detection dogs. The results of this work were ambiguous.

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